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Crisis Crowdsourcing Framework: Designing Strategic Configurations of Crowdsourcing for the Emergency Management Domain

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Abstract. Crowdsourcing is not a new practice but it is a concept that has gained substantial attention during recent disasters. Drawing from previous work in the crisis informatics, disaster sociology, and computer-supported cooperative work (CSCW) literature, this paper first explains recent conceptualizations of crowdsourcing and how crowdsourcing is a way of leveraging disaster convergence. The CSCW concept of "articulation work" is introduced as an interpretive frame for extracting the salient dimensions of "crisis crowdsourcing." Then, a series of vignettes are presented to illustrate the evolution of crisis crowdsourcing that spontaneously emerged after the 2010 Haiti earthquake and evolved to more established forms of public engagement during crises. The best practices extracted from the vignettes clarified the efforts to formalize crisis crowdsourcing through the development of innovative interfaces designed to support the articulation work needed to facilitate spontaneous volunteer efforts. Extracting these best practices led to the development of a conceptual framework that unpacks the key dimensions of crisis crowdsourcing. The Crisis Crowdsourcing Framework is a systematic, problem-driven approach to determining the why, who, what, when, where, and how aspects of a crowdsourcing system. The framework also draws attention to the social, technological, organizational, and policy (STOP) interfaces that need to be designed to manage the articulation work involved with reducing the complexity of coordinating across these key dimensions. An example of how to apply the framework to design a crowdsourcing system is offered with a discussion on the implications for applying this framework as well as the limitations of this framework. Innovation is occurring at the social, technological, organizational, and policy interfaces enabling crowdsourcing to be operationalized and integrated into official products and services.

Keywords: Articulation work, Conceptual framework, Crisis informatics, Crisis mapping, Crowdsourcing, Crowdwork, Digital volunteers, Disasters, Emergency management, Human computation, Information management, Social media

1. Introduction

Crowdsourcing is not a new practice but it is a concept that has gained substantial attention in the crisis domain and emergency management community. The ubiquity of emerging information and communication technologies (ICTs)—including social

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media platforms, location-aware mobile devices, open source software, and cloud computing services—has made this participatory practice become more digitally-enabled and collaborative in the networked world. Researchers are extracting best practices by looking at new as well as established applications of how crowdsourcing can address information dearth and overload issues during emergencies to potentially save lives and foster disaster risk reduction.

Crowdsourcing is often oversimplified. Multiple crowdsourcing configurations are often needed to strategically leverage the people, information, and resources that converge during crisis situations. Oftentimes, crowdsourcing is too broadly or narrowly defined to refer to a wide range of collective behavior emerging online particularly with social media, resulting in nebulous interpretations of this term. To put simply, crowdsourcing is a dynamic form of cooperative work involving a large and often indeterminate number of civic participants conducting semi-autonomous tasks to address information management issues. This type of mass collaboration typically occurs in a distributed way often leveraging social networking technologies to facilitate coordination among different crowds. But what kind of problems can be alleviated with the help of crowds during a crisis? What type of information or service may be needed from certain crowds? What kind of strategies have enabled or hindered crowdsourcing efforts during disasters? A conceptual framework of crisis crowdsourcing is needed for crisis informatics researchers, emergency management practitioners, digital volunteer communities, as well as ICT developers of crowdsourcing systems.

This paper extends theories of ICT-enabled public participation and emergent social media use in disasters by offering a conceptual framework for articulating the cooperative work involved with crisis crowdsourcing. A series of vignettes illustrating the evolution and formalization of crisis crowdsourcing are presented to uncover the best practices that informed the development of the framework. The Crisis Crowdsourcing Framework provides guidance on strategically identifying the key dimensions as well as the social, technological, organizational, and policy interfaces to consider when designing a crisis crowdsourcing project or system. An example of how to apply the framework is offered to inform the design of a crowdsourcing system called iCoast. This paper concludes with implications of applying this framework to the computer-supported cooperative work (CSCW) and the field of crisis informatics to extend concepts of "articulation work" based on an emerging form of cooperative work occurring through networking technologies during disasters.

2. Related work

Crisis informatics. (Hagar and Haythornthwaite 2005; Palen et al. 2009; Palen et al. 2010) is an emerging field concerned with the social, technical, and informational aspects of emergency response. It is an interdisciplinary field that weaves together theories from disaster sociology and qualitative phenomenological research methods from CSCW to understand social computing and online behavior during disasters. This section discusses recent conceptualizations of crowdsourcing and explains how "disaster convergence" (Fritz and Mathewson 1957; Kendra and Wachtendorf 2003) has led to emerging forms of crowdsourcing in the crisis domain. Then, the CSCW concept of "articulation work" is introduced as an interpretive frame for extracting the salient dimensions of crisis crowdsourcing.

2.1. Conceptualizations of ICT-enabled crowdsourcing

Crowdsourcing is a nebulous, loosely defined concept associated with a wide range of public participation activities that have occurred in practice. The growing popularity of online and ICT-based crowdsourcing arose from the coining of the term by Howe (2006); Howe 2008 in a Wired magazine article, and Snow et al.'s (2008) research on Amazon's Mechanical Turk[1] crowdsourcing system. Initial studies of online crowdsourcing systems like Mechanical Turk focused on how to support micro-tasking—the process of taking a large task and breaking it down into a series of smaller human intelligence tasks. Micro-tasks make it easy to analyze technology-supported civic participation to inform machine-learning techniques. There has been a growing interest among HCI and CSCW researchers to analyze established, top-down crowdsourcing systems like Mechanical Turk. They are conducive to recruiting cheap research participants and for studying human computation—harnessing human intelligence to solve computational problems—in the wild, but they do not represent the array of ICT-based crowdsourcing that spontaneously emerges after disasters.

Crowdsourcing in the networked world often integrates multiple ICTs to incorporate varying flows of interaction, depending on the type of media needed to communicate between crowdsourcing actors. Roche et al. (2011) offer helpful distinctions between four types of communication paradigms for disseminating information. The 'one-to-many' paradigm uses a centralized architecture for top-down dissemination from one transmitter to a multitude of receivers through venues like broadcast radio, television, and the Internet. The 'many-to-one' paradigm uses a decentralized architecture but centralizes the dissemination of information from a multitude of transmitters and receivers through services like content aggregators. The 'many-to-many' paradigm uses a decentralized architecture to disseminate information among a multitude of transmitters and receivers by using services like social networking platforms. The 'one-to-one' paradigm uses a meshed architecture to generate an exchange between one transmitter to another through devices like mobile phones and services like text messages.

An ecosystem of old and new ICTs is enabling particular crowdsourcing practices to emerge. Distinguishing and recognizing the affordances of each ICT for communicating and disseminating information has led to more strategic forms of crowdsourcing. "We use Facebook to schedule protests, Twitter to coordinate and YouTube to tell the world" is a tweet from an Egyptian activist that is frequently cited in online articles and blogs in response to the 2011 Arab Spring. It is a simple reflection of how crowds of activists use social media to collaborate by strategically using certain social media platforms to coordinate at micro scales and others to communicate at macro scales. Recent ad hoc crisis crowdsourcing efforts are unveiling new questions and issues around using ICTs to engage and coordinate with the wider public especially during disasters.

Over the past few years, researchers in various fields have offered broad characterizations of crowdsourcing applicable to multiple domains (e.g., Brabham 2008; Brabham 2012; Estellés-Arolas and González-Ladrón-de-Guevara 2012; Gao et al. 2011; Heipke 2010; Heinzelman and Waters 2010; Martineau 2012; Meier 2011; Rouse 2010; Schenk and Guittard 2011; Sharma 2010; Yates and Paquette 2011). Crowdsourcing studies like Gao et al. (2011) and Teraguchi et al. (2012) tend to use the term in a broad way discussing only partial aspects of crowdsourcing without specifying, for example, what type of crowd may be needed. Other research studies focus on characterizing crowdsourcing based on its relation to other concepts, such as outsourcing, open source, citizen science, collective intelligence, and human computation (e.g., Cobb et al. 2014; Boulos et al. 2011; Goodchild and Alan Glennon 2010; Starbird 2012; 2013).

Starbird (2012), p. 283) "crowdwork continuum framework" provides a helpful starting point for understanding how technology-supported civic participation has evolved during disasters, but it "does not provide a method for classifying all varieties of crowd work." What is missing in the literature on crowdsourcing is an approach to understanding the coordination work involved with engaging different crowds in the context of disasters. Additionally, in the Disaster Relief 2.0 report, the Harvard Humanitarian Initiative (2011) stated the need for "a clear operational interface that outlines ways of collaborating before and during emergencies, with agreed procedures for communication, shared standards for data exchange and an understanding of roles, priorities and capabilities."

2.2. Disaster convergence and improvisation

The disaster sociology literature offers an instructive starting point for understanding why and how crowdsourcing has emerged during large-scale crises involving the emergency management community. Disaster situations are a result of hazards with varying predictabilities in a time-pressured environment. The increase in uncertainty during crises often leads to complex response efforts with broad societal consequences. Interdisciplinary and multi-stakeholder collaborations are critical for enhancing situational awareness among affected-populations, emergency responders, decision-makers, and volunteers.

Disaster sociologists (e.g., Dynes 1970; Kreps and Bosworth 1994; Quarantelli and Dynes 1977; Stallings and Quarantelli 1985) have long developed empirical taxonomies to describe the collective behavior and convergence that arise from disaster situations. Public participation during crises was originally viewed as a problem because of the negative effects of “disaster convergence” like mass-coordination challenges (Fritz and Mathewson 1957; Kendra and Wachtendorf 2003). This type of disaster convergence occurs when too many people physically converge in the affected region creating liability and personnel management issues for official responders. Convergence also occurs when a deluge of resources and information need to be processed and managed. Coordinating this convergence often leads to “disaster improvisation,” where stakeholders in the crisis domain experiment with innovative ways of leveraging each other’s diverse skills, expertise, and resources to adapt to the uncertainty that arises from crisis situations (Dynes 1970; Fritz and Mathewson 1957; Kendra and Wachtendorf 2003; Wachtendorf, Tricia and James M. Kendra 2005; Mendonça 2007).

The digital convergence of people, information, and resources during crises is increasingly taking place on social media platforms and well-documented in various papers in the field of crisis informatics (e.g., Palen, Leysia and Sophia B. Liu 2007. Citizen Communications in Crisis: Anticipating a Future of ICT-Supported Participation. Proceedings of the 2007; Hughes et al. 2008; Hughes and Leysia Palen 2009; Starbird et al. 2010; Vieweg et al. 2010; Starbird and Palen 2011; Qu et al. 2011; Mark et al. 2012; Sarcevic et al. 2012). In particular, Starbird and Palen (2011) expand on the concept of “emergent groups” from the disaster sociology literature to examine how digital volunteers self-organize and engage in information processing activities to address the unmet needs of the emergency management community.

Crowdsourcing has been credited as serving an important role during crises, but it is an ambiguous term that tends to be “employed as a blanket descriptor for a variety of activities…obscuring the complexity of human behaviors and computational systems that support them” (Starbird 2012, p. 25–26). Wald et al. (2011), p. 688) have even argued that the U.S. Geological Survey “Did You Feel It?” (DYFI) online questionnaire—described later in more detail—is a noteworthy example of how “systemic collection of citizen-provided data has preceded the use of the formal concept of ‘crowdsourcing’ by more than a decade.” Within the crisis informatics community, Starbird (2012) introduced the term “crowdwork” and a “crowdwork continuum framework” to characterize the evolution of crowdsourcing based on the spontaneous and episodic behaviors of digital volunteers during disaster response and humanitarian relief efforts. Starbird and Palen’s (2013, p. 491) recent ethnographic study of a virtual volunteer organization called Humanity Road empirically analyzes how this organization evolved from “improvised ways of operating in the chaotic information space to an increasingly established organization with a steadier social structure, identity, production functions, rules and procedures.”

Crisis crowdsourcing is a type of cooperative work emerging from improvised uses of ICT to leverage and manage the convergence of crowds, information, and resources to address emergency management needs. What is lacking in the field of crisis informatics is a conceptual framework for understanding the complex coordination and interaction mechanisms to integrate and operationalize crisis crowdsourcing into the official emergency management environment.

2.3. The articulation work of crowdsourcing

CSCW is a design-oriented research field to support collaborative systems by understanding the "nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies" (Bannon et al. 1989). This paper focuses on understanding the cooperative work involved in crisis crowdsourcing to better support the mass-coordination challenges emerging from this phenomenon. The concept of "articulation work" coined by Strauss (1988, 1993) was introduced to the CSCW field as an analytical framework for understanding the communication and coordination mechanisms of cooperative work involving mutually dependent actions and collaborating actors (Strauss 1993; Strauss 1985; Schmidt and Bannon 1992; Schmidt 1994; Simone et al. 1995; Divitini and Tuikka 1996; Fitzpatrick et al. 1995; Fjuk et al. 1997). Articulation work encompasses "a set of activities required to manage the distributed nature of cooperative work" (Schmidt and Bannon 1992, p. 12), or rather "a kind of supra-type of work in any division of labor, done by the various actors" (Strauss 1985, p. 8). Some have defined this socio-technical concept as simply "work that supports other work" (Baker and Millerand 2007) in terms of activities relating to planning, organizing, monitoring, evaluating, adjusting, coordinating, negotiating, and integrating activities" (Fujimura 1987).

Articulation work is also referred to as the invisible coordination and negotiation activities necessary to get the work done (Gerson and Star 1986; Schmidt and Bannon 1992; Grinter 1996; Bowker and Star 1999). People tend to facilitate this invisible coordination work by making their activities visible in some way to other workers (Heath and Luff 1992). Much of what has enabled crisis crowdsourcing is the articulation work involved with coordinating crowds, information, and resources that converge during disasters. The articulation work is increasingly visible through digital traces in a myriad of ICTs that can be remotely investigated. Bowker and Star (1999) assert that articulation work is a way to manage the consequences that arise from coordinating distributed work, and are especially challenging to design because interruptions to routine work engender real-time contingencies and "situated action" (Suchman 1987). Strauss (1988) also coined the term "articulation process" to refer to "the specifics of putting together tasks, task sequences, task clusters – even aligning larger units…– in the service of work flow…the overall process of putting all the work elements together and keeping them together." The series of vignettes presented here illustrate how the formalization of crisis crowdsourcing resulted in the development of innovative interfaces that support the articulation work and processes needed to augment, rather than disrupt, existing emergency management operations.

3. Methods

A qualitative phenomenological research study was conducted to understand the conceptualizations of crowdsourcing and their evolution in the crisis domain. The purpose of this study was to capture shared experiences from key stakeholders who have engaged in crisis crowdsourcing in some manner. The first author initially conducted approximately 80 open-ended interviews in New York City and the Washington, D.C. area targeting stakeholders that have engaged in crisis crowdsourcing—namely humanitarian agencies, state and local emergency responders, nongovernmental organizations, non-profit organizations, geospatial companies, technology companies, mainstream and local media outlets, crisis informatics researchers, and digital volunteer communities. Participant observations were also conducted online at crowdsourcing training sessions, as well as in the field at multi-stakeholder expert meetings and crowdsourcing-related field experiments and exercises. Then, the scientific literature on crowdsourcing and online documents like blog posts self-reporting on recent crowdsourcing efforts were revisited to extract themes and identify critical gaps in conceptualizing crowdsourcing in a systematic way for the crisis domain.

Findings from this study uncovered different configurations of crisis crowdsourcing that were then organized into a framework. The Crisis Crowdsourcing Framework is intended to extend Starbird's (2012) "crowdwork continuum framework" by using the concept of "articulation work" as an interpretive frame for characterizing the cooperative work involved with crowdsourcing in relation to tasks, workers, workflows, and common information spaces. Then, an example is presented on how the framework was applied to develop a crisis crowdsourcing system called "iCoast – Did the Coast Change?" using participatory design methods to identify multiple configurations for integrating crowdsourcing practices into official U.S. Geological Survey (USGS) products and workflows.

4. Crisis crowdsourcing vignettes

Before the Crisis Crowdsourcing Framework is introduced, a series of vignettes is presented illustrating the evolution of crisis crowdsourcing that spontaneously emerged after the 2010 Haiti earthquake resulting in more established forms of public engagement during crises. The vignettes provide a snapshot of how the formalization of crisis crowdsourcing engendered the development of innovative interfaces designed to support the articulation work that was needed during the spontaneous efforts.

4.1. Emergence of crisis mapping after the Haiti earthquake

Mapping crisis information is not entirely new; yet, over the past five years, there has been an increase in real-time mapping activities emerging from crisis-related technology communities. Nourbakhsh et al. (2006, p. 787) foresaw this "emergence of a new breed of volunteers—online data managers" facilitating a "web-based community approach to disaster operations." There is an increasing need to map these data to gain better situational awareness. Since 2009, the International Network of Crisis Mappers[2] and their annual conference have facilitated discussions and deployments at the intersection of humanitarian crises, technology, crowdsourcing, and crisis mapping (Liu and Ziemke 2012). The 2010 Haiti earthquake was the tipping point for realizing the value of the OpenStreetMap platform for addressing the lack of baseline or current maps of Haiti to inform humanitarian relief efforts.

4.1.1. *OpenStreetMap (OSM) and the "Imagery to the Crowd" project*

Just a few hours after the Haiti earthquake, the Humanitarian OpenStreetMap Team (HOT)[3] coordinated with the OpenStreetMap (OSM) volunteer community, as well as other emerging digital volunteer networks like CrisisCommons[4] to digitally map Haiti using the OSM platform (Heinzelman and Waters 2010; Meier and Munro 2010; Zook et al. 2010; Harvard Humanitarian Initiative 2011). The "OpenStreetMap – Project Haiti" Vimeo video[5] created by ItoWorld presents a time lapse visualization of the OSM edits to illustrate how quickly the mapping of Haiti occurred immediately after the earthquake. Within the first month, over 600 volunteers mapped roads while marking the impassable ones and mapped humanitarian features such as internally displaced persons camps.

Crisis mappers initially searched for existing geospatial data and available satellite imagery of Haiti to trace into OSM. Talbot Brooks, a professor affiliated with the Center for Interdisciplinary Geospatial Information Technologies at Delta State University in Mississippi, digitized and shared very high-resolution satellite imagery of Haiti from old Central Intelligence Agency (CIA) maps, allowing OSM volunteers to remotely map Haiti. The base map of Haiti in OSM before the earthquake was quite old containing edits made in the aftermath of Hurricanes Ike, Hanna, and Gustav in 2008. Initially, the volunteers enhanced the base map by tracing roads visible from Yahoo! satellite imagery, but 48 hours later, the OSM community was able to access post-earthquake satellite imagery from GeoEye and DigitalGlobe. Typically this type of imagery is expensive to acquire with legal restrictions regarding who can access the imagery and how it can be used. However, in the disaster climate, there was an incentive to publicly and freely share this imagery to enhance coordination efforts among the humanitarian response community.

In August 2011 at the Naval Postgraduate School's Research & Experimentation for Local & International Emergency & First-Responders (RELIEF) Experiment, the

Humanitarian Information Unit (HIU) at the U.S. State Department and the National Geospatial-Intelligence Agency (NGA) began working with HOT to explore ways of sharing high-resolution, commercial satellite imagery with volunteers for the purpose of digitally mapping disaster-affected areas. This collaboration required a change to NextView's Imagery End User License policy agreement to allow OSM volunteers to legally and freely view, but not download or edit, expensive imagery for the sole purpose of remotely processing satellite imagery for humanitarian crises, according to Joshua Campbell[6]—the geographer and GIS architect at HIU who developed this Imagery to the Crowd[7] workflow with NGA and HOT.

Mapping immediately after a disaster revealed that better coordination tools were needed to more efficiently collaborate and coordinate OSM volunteers editing at the same time and place on the OSM map. Initially, volunteer mappers coordinated through the OSM Haiti WikiProject website, IRC channels, and the OSM talk list. There was a need to reduce the complexity of coordinating OSM mapping tasks among OSM volunteers during a crisis. Through funding from the Australia-Indonesia Facility for Disaster Reduction, the OSM Tasking Manager[8] was established in September 2011 as a micro-tasking platform to coordinate large OSM mapping efforts by breaking down satellite imagery into smaller geographic regions or square tiles to create mapping tasks that could be completed in 30 or 60 minutes (Figure 1). The Tasking Manager allows administrators to more efficiently coordinate the mapping task remotely by providing an indication of where map edits are occurring and where further mapping efforts should be focused. This manager tool explains the mapping task, shows the workflow of the task, highlights OSM volunteers that have contributed, and provides statistics of the crowd-mapping progress.

In early 2013, HIU developed a website called MapGive[9] to "harness the combined power of satellite imagery and the volunteer mapping community to help aid agencies provide informed and effective humanitarian assistance, and plan recovery and development activities." High-resolution commercial satellite imagery purchased by the United States Government can now be rapidly shared online to the volunteer mapping community with the adaptation of NextView's imagery sharing license. The MapGive website also integrates the OSM Tasking Manager to automatically divide the satellite imagery into smaller sections, allowing volunteers to easily self-organize and coordinate the crowd-mapping task for each crisis project.

4.1.2. *Mission 4636 and Ushahidi-Haiti*

Although traditional emergency reporting systems had failed after the Haiti earthquake, cell phone towers were still operational enough to send low-bandwidth SMS text messages—the primary means of communication in Haiti. To leverage this existing communication channel, Josh Nesbit from

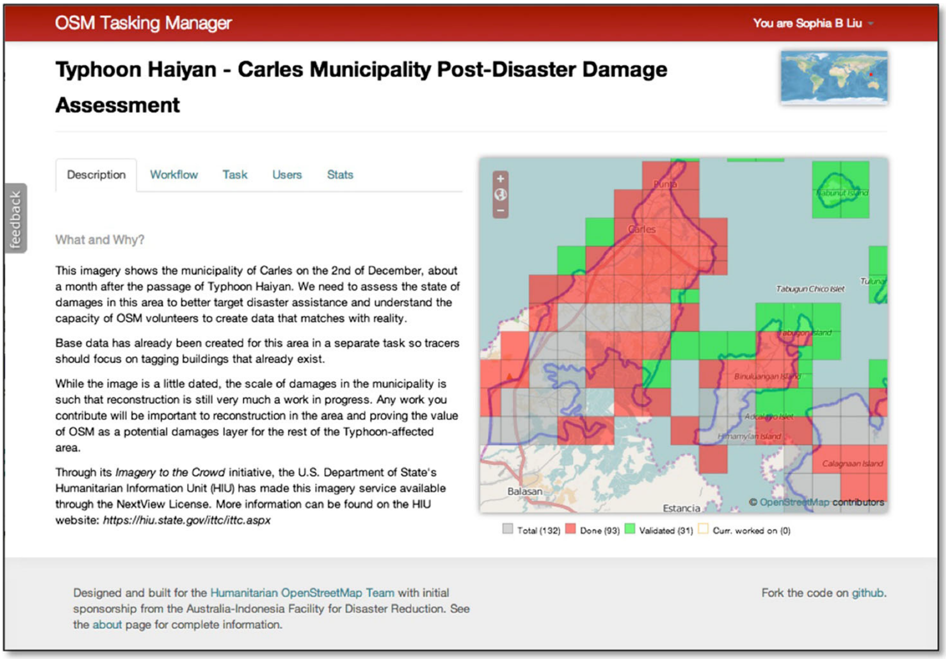


Figure 1. Screenshot of the OSM tasking manager for coordinating the post-disaster damage assessment mapping efforts after Typhoon Haiyan in 2013.

FrontlineSMS: Medic and Katie Stanton from the U.S. State Department collaborated with Digicel—the largest mobile telecommunications company in Haiti—to set up the 4636 short code and allow anyone in Haiti to send free SMS text messages about their urgent needs (e.g., missing people reports and requests for medical care, food, water, and shelter). Robert Munro (chief information officer at Energy For Opportunity) and Brian Herbert (web developer at Ushahidi) recognized the need for a micro-tasking translation system that involved three tasks for handling the 4,636 messages: (1) translating the SMS messages into English, (2) geocoding them so that they could appear on interactive maps, and (3) categorizing them to make actionable information searchable for the humanitarian response community.

Within 48 hours, the SMS-based Mission 4636 initiative was developed (see Heinzelman and Waters 2010; Hester et al. 2010; Meier and Munro 2010; Zook et al. 2010; Harvard Humanitarian Initiative 2011; Munro 2012). One part of Mission 4636 was promoted inside Haiti through the local radio and word-of-mouth to reach earthquake-affected populations asking them to send text messages about their urgent needs. Another part of Mission 4636 was promoted outside of Haiti online and through social media, and focused on looking for Haitian diaspora as well as Haitian-Kreyòl and French-speakers willing to volunteer their time to translate, geocode, and categorize the 4636 messages.

Initially, this crowdsourcing workflow was improvised through a variety of existing platforms and partnerships. Robert Munro, the primary volunteer coordinator of Mission 4636, mobilized over 1,000 volunteers from 49 countries. These volunteers were mostly from the Haitian diaspora that he quickly found through Facebook groups and by word-of-mouth, as well as crisis relief specialists and professional translators. Leveraging the Haitian diaspora's local knowledge of their native language and geography helped to bridge the crisis-affected population in Haiti with the international relief efforts.

Eventually the commercial crowdsourcing platform called CrowdFlower was used to transfer this volunteer crowdsourcing effort to paid workers in Haiti through Samasource, a partner of CrowdFlower that had already trained a small group of Haitians in Mirebalais on how to do online micro-tasking (Hester et al. 2010). These Haitian crowd workers received \$0.25 for each translation, \$0.20 for each geocoding, \$0.10 for creating a missing person record, and \$0.05 for each categorization. About 80,000 messages were translated and geocoded by 2,000 digital volunteers and paid workers; more than 1,000 messages were received per day and were processed on average within 10 min of receipt over a 3-month operation (Munro 2012).

4.2. The formalization of digital volunteer networks and practices into protocols

Just hours after the Haiti earthquake, Patrick Meier and David Kobia from Ushahidi launched the Ushahidi-Haiti[10] platform to crowdsourced crisis reports via text messages, email, and other online sources (Heinzelman and Waters 2010; Meier and Munro 2010; Harvard Humanitarian Initiative 2011; Liu and Ziemke 2012). They improvised ways to translate, geocode, categorize, verify, and ultimately curate information online by manually combing through social media data and other online sources to find actionable information useful for the humanitarian relief community. This effort led to further deployments of the Ushahidi platform and the development of the CrowdMap[11] service to easily allow an Ushahidi instance to be set up in a cloud-computing environment.

After this spontaneous crowdsourcing effort, there was an urge to streamline the spontaneous crowdsourcing efforts by establishing digital volunteer networks, and formalizing their crowdsourcing practices and protocols. In this vignette, the evolution of one digital volunteer community and the establishment of the Digital Humanitarian Network to enable and legitimize these types of digital volunteer networks are discussed.

4.2.1. *Standby Task Force (SBTF)*

The Standby Task Force[12] (SBTF) is a volunteer technology community (VTC) of digital volunteers that was formed in late 2010 after the spontaneous crisis mapping activity following the Haiti earthquake. These volunteers refer to themselves as "digital humanitarians" that have streamlined the online and real-time surge support needed for processing large amounts of crisis data during a disaster to help responders on-the-ground. SBTF is a loose, informal network of volunteers distributed worldwide with various skills and backgrounds, including geographers, development and humanitarian professionals, transparency advocates, and data scientists.[13] Shadrock Roberts, a SBTF volunteer and senior spatial analyst at the United States Agency for International Development (USAID), explained in an interview that SBTF volunteers "feel like they are a part of a community" because of the social relationships and ongoing conversations they have developed through the use of ICTs like Skype Chat. SBTF is also described as providing a platform or shared space to enable this kind of virtual community engagement, which Roberts argues is oftentimes more important than the outcome of the crowdsourcing effort.

SBTF has formalized their online crowdsourcing activities by developing an activation protocol and then self-organizing into task-based teams. The activation protocol[14] is an organizational interface for collaborating more directly with local and international humanitarian response agencies. Each of the task-based teams has developed workflows and trainings to bring together volunteers with similar skills, knowledge, and abilities. The current refinement of their team structure is the (1) Monitoring & Evaluation, (2) Verification, (3) Geo-Location, (4) Data, Mapping & Analysis, and (5) Task & Research Teams.

4.2.2. *Digital Humanitarian Network (DHNetwork)*

As these digital volunteers and communities continued to evolve and formalize their crowdsourcing practices, Andrej Verity and Patrick Meier established the Digital Humanitarian Network[15] (DHNetwork) launched in April 2012 as a network-of-networks enabling a consortium of VTCs to interface with humanitarian organizations needing their service. The DHNetwork is officially a member of the global Inter-Agency Information Management Working Group led by the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) in connection with Andrej Verity, a disaster responder and information management officer at UNOCHA. The purpose of establishing this network of VTCs is to stimulate innovation among these digital communities and offer a centralized way of putting a call out to established-VTCs that can provide digital volunteer services immediately for the humanitarian response community.

Immediately after Typhoon Bopha/Pablo that hit the southern Philippine island of Mindanao in December 2012, UNOCHA activated SBTF through the DHNetwork organizational interface and requested that digital volunteers (1) collect all relevant tweets from Twitter posted on December 4th and 5th when the typhoon made landfall; (2) identify pictures and videos of damage and flooding in those tweets; (3) geo-locate, time-stamp, and categorize them; and then (4) compile a customized Situation Report with maps, charts, and figures for OCHA's team in the Philippines.[16] Together, the Standby Task Force and another VTC called Humanity Road analyzed over 20,000 tweets in 24 hours using Geofeedia,[17] a location-based social media monitoring platform, to identify all relevant geotagged pictures and videos. SBTF also partnered with the Qatar Foundation Computing Research Institute's Crisis Computing Team to analyze the tweets using algorithmic and human computation methods.

4.3. Establishment of citizen seismology at the U.S. Geological Survey

While crisis crowdsourcing has emerged and formalized over recent years, a parallel development in citizen science has also formalized systematically engaging citizens to participate in science at a massive scale through virtual platforms. "Citizen science" or "public participation in scientific research" is a growing field that is over a century old, where protocols are developed to increase public participation and awareness for the purposes of advancing scientific knowledge and education (Trumbull et al. 2000; Cohn 2008; Bonney et al. 2009; Newman et al. 2011; Newman et al. 2012; Shirk et al. 2012; Hines et al. 2013). Citizen scientists are valuable because they can gather data to answer real-world issues that are difficult for scientists to collect at large geographic scales over long periods of time (Cohn 2008). Citizen science projects related to natural hazards often involve government agencies, conservation groups, and other stakeholders who monitor environmental trends, set conservation priorities, and change land-use policies and regulations. More recent forms of citizen science are emerging through the use of location-aware devices and social networking platforms.

"Citizen seismology" is an emerging field that investigates and experiments with public engagement to improve earthquake detection and alert systems (Bowser and Shanley 2013; Earle et al. 2011). The USGS has been at the forefront in demonstrating how to divide and assign tasks to citizens, motivate users to continue participating, and combine citizen responses to produce actionable products and services for the emergency management community, particularly through the USGS "Did You Feel It?" and Tweet Earthquake Dispatch projects.

4.3.1. *"Did You Feel It?" (DYFI)*

In 1999, the USGS harnessed the opportunity to rapidly collect data via the Internet about shaking intensities directly from people who felt earthquakes. Wald et al. (1999a) developed an online questionnaire called "Did You Feel It?" (DYFI)[18] that asks earthquake-affected populations a series of questions about observable shaking effects, such as "Did pictures on walls move or get knocked askew?" and "Was a heavy appliance (refrigerator or range) affected?" DYFI is a "citizen-based science endeavor" where contributors do not need to be trained to fill out these short, easy-to-use online forms—unlike other citizen science projects that may require training to use specialized field instruments (Wald et al. 2011).

The DYFI response rates have reached as high as 62,000 responses per hour or roughly 1,000 entries per minute for widely felt earthquake events, and has received more than 2,790,000 total responses since its inception (Wald et al. 2011; Bowser and Shanley 2013). DYFI was the solution to eliminating the need for processing large quantities of questionnaires collected by telephone interviews and postal mail, and then subjectively assigning numerical intensities to individual intensity reports (Wald et al. 2011). These qualitative observations are automatically turned into quantitative shaking intensity values, and then mapped at the zip code or city level to create Community Internet Intensity Maps (CIIM). DYFI reports are also used as inputs immediately following large earthquakes to constrain the Global ShakeMap system (Wald et al. 1999b). DYFI reports are also used as hazard inputs for the USGS Prompt Assessment of Global Earthquakes for Response (PAGER) system (Wald et al. 2006).

4.3.2. *Tweet Earthquake Dispatch (TED)*

The USGS Tweet Earthquake Dispatch (TED) system[19] is another citizen seismology project that began in 2010 investigating how the social networking site Twitter—a social media platform for sending and receiving short, public text messages—can augment USGS earthquake response products and the delivery of official earthquake hazard information (Earle et al. 2010; Guy et al. 2010; Earle et al. 2011; Liu et al. 2012; Young et al. 2013). Social media platforms are increasingly being used to rapidly share qualitative experiences of shaking from seismic events. Real-time harvesting of this public data using data mining techniques is a way of passively collecting data from crowds online involuntarily without direct consent—an approach that does not involve direct engagement with the public.

The TED system rapidly detects widely felt seismic events through a simple, real-time event detector system that solely harvests Twitter data based on spatiotemporal trends. The detector uses a short-term-average over long-term-average algorithm that is commonly used in seismology to detect and measure seismic phases (Earle and Shearer 1994). The algorithm is also configurable to suppress false triggers from high volume tweets unrelated to seismic events. A tweet-frequency time series is constructed from tweets containing the word "earthquake" or its equivalent in other languages. The real-time detection system scans for significant increases in earthquake-related tweets and sends TED alerts to beta test users with the TED detection time, tweet text, and location of the nearest city where most of the tweets originated.

TED is a real-time earthquake detection system that produces approximately two or three detections per day typically occurring within two minutes of the origin time of an earthquake with a false detection rate of less than 10 % (Earle et al. 2011; Liu et al. 2012; Young et al. 2013). Tweet-based detections are sometimes faster than traditional seismic monitoring networks in poorly instrumented regions of the world. Figure 2 illustrates a TED alert detected approximately 20 s after the origin time of the 4.0 magnitude earthquake at Hollis Center, Maine in October 2012. Twitter offers another and potentially faster mechanism to discover these smaller seismic events.

TED is in no way a replacement for a network of seismic instruments, since these tweet-based detections do not provide accurate enough information for formal impact assessments. Instead, the TED system augments instrumentally derived data at the USGS. The real-time, low cost access to earthquake tweets not only provides short, first-hand narratives of shaking experiences, but also the ability to discover earthquakes in sparsely instrumented regions sometimes before instrumentally derived seismic data are obtained (Earle et al. 2011; Liu et al. 2012; Young et al. 2013).

4.4. Extracting the articulation work of crisis crowdsourcing

The vignettes illustrate two parallel developments of crowdsourcing in the crisis domain. The spontaneous digital volunteerism after the Haiti earthquake led to the development of workflows and protocols to more directly inform response, recovery, and rebuilding efforts. The articulation work became quite complex and demanding on the digital volunteers that they needed and wanted to formalize themselves and their crowdsourcing practices to reduce the complexity of coordinating their distributed crowd work. Citizen-based science efforts in the hazards domain have had a longer history with public engagement, but are also evolving with the emergence of social media and other ICTs. Such efforts approach hazards as an ongoing future threat and tend to develop crowdsourcing applications to refine hazard and vulnerability assessments. Both developments of crisis crowdsourcing exhibit best practices around developing interfaces that formalize the “articulation work” and “articulation processes” needed for enabling crowdsourcing efforts to directly inform emergency management.

The innovative interfaces worth noting from the crisis crowdsourcing vignettes are (1) the development of the MapGive website that integrates the Imagery to the Crowd workflow and HOT’s OSM Tasking Manager; (2) the development of the Mission 4636 initiative that tapped into the Haitian diaspora; (3) the Ushahidi platform and CrowdMap cloud service; (4) the creation and formalization of the Standby Task Force teams, workflows, and protocols; (5) the establishment of the Digital Humanitarian Network; and (6) the integration of DYFI and TED citizen seismology applications with official earthquake products and services at the USGS. These interfaces are not necessarily just technological ones, but they also weave in the social,

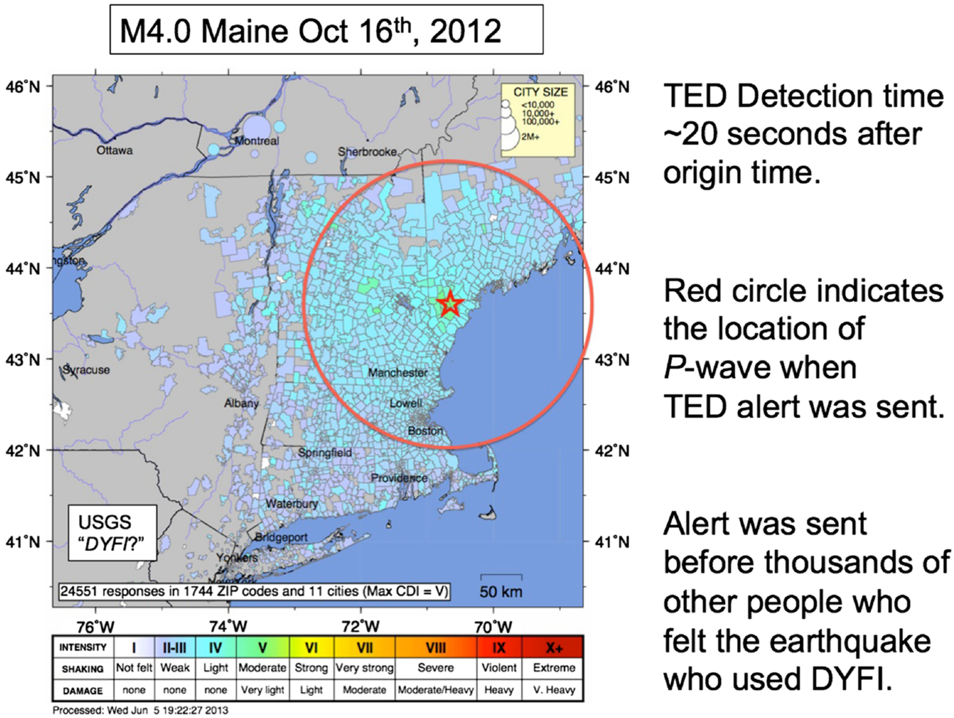


Figure 2. USGS Tweet Earthquake Dispatch (TED) system sent the TED alert 20 seconds after the origin time of the magnitude 4.0 Maine earthquake in 2012.

organizational, and policy interfaces that are critical to enabling, mainstreaming, and operationalizing crowdsourcing in the emergency management environment.

In the case of the MapGive website, the Imagery to the Crowd workflow and the OSM Tasking Manager are separate types of "articulation work" brought together to support a larger "articulation process" of coordinating crowdmapping activities for humanitarian crises. SBTF developed multiple task-based teams and workflows to engender consistent coordination efforts among the SBTF volunteers. SBTF also developed an "articulation process" that brought together all their teams and made their articulation work and process visible through Google Docs, Ning, and Skype Chats.

The Mission 4636 initiative, the Ushahidi-Haiti map, and the Standby Task Force teams are all novel crisis crowdsourcing interfaces that were entirely volunteer-driven and established informally outside of official agencies. MapGive, the Digital Humanitarian Network, and the development of USGS citizen seismology applications are also novel interfaces but were initiated from inside of organizational and institutional channels typically at government agencies. What these formalized interfaces uncover is a strategic alignment of different crowds, information, and resources to resolve coordination conflicts that arise from crowdsourcing.

The purpose of developing these innovative interfaces was ultimately to reduce the complexity of coordinating that occurred during the spontaneous crowdsourcing efforts after the Haiti earthquake. These interfaces also helped to legitimate and streamline crowdsourcing practices to make them reusable for future crises. Official and informal crisis crowdsourcing interfaces are beginning to merge. However, a more systematic treatment of crowdsourcing is needed to provide the basis for comparative work on crowdsourcing. Moreover, a framework is needed to strategically inform the design and development of innovative interfaces to operationalize crowdsourcing for the emergency management domain.

5. Crisis crowdsouring framework

Crisis crowdsourcing encompasses a set of coordination activities for managing the distributed nature of this collaborative work. Specifying the distributed activities involved with crowd work helps to determine how to partition this work into semi-autonomous micro-tasks—the interaction mechanisms needed to coordinate with key stakeholders. The Crisis Crowdsourcing Framework unpacks and delineates six key dimensions of crisis crowdsourcing to offer guidelines for designing and developing interfaces that reduce the complexity of coordinating in these environments.

The framework applies CSCW's concept of "articulation work" and "articulation process" to uncover the essential components that enable cooperative work within crisis crowdsourcing. Fjuk et al. (1997) explain the term "articulation" by specifying the salient dimensions of cooperative work according to the who (individual actors), what/why (actions, outcomes, objectives), where/when (spatiotemporal context of actions), and how (process of putting the actions into operation) dimensions. Schmidt (1993) also uses the same information-gathering dimensions to explain the "mechanisms of interaction" that can be designed "to reduce the complexity and cost of articulating the distributed activities of a cooperative work arrangement by regulating and mediating the articulation of the distributed activities: who is to do what, where, when, how etc."

The Crisis Crowdsourcing Framework uses the same information-gathering dimensions of why, who, what, when, where, and how to articulate the interaction mechanisms that crisis informatics researchers, designers of crowdsourcing systems, emergency management and hazards practitioners, and digital volunteer communities should consider when designing a crowdsourcing system in the crisis domain. The framework incorporates the different contingencies caused by crises to determine the interaction mechanisms needed to enable crisis crowdsourcing. Figure 3 assembles the six

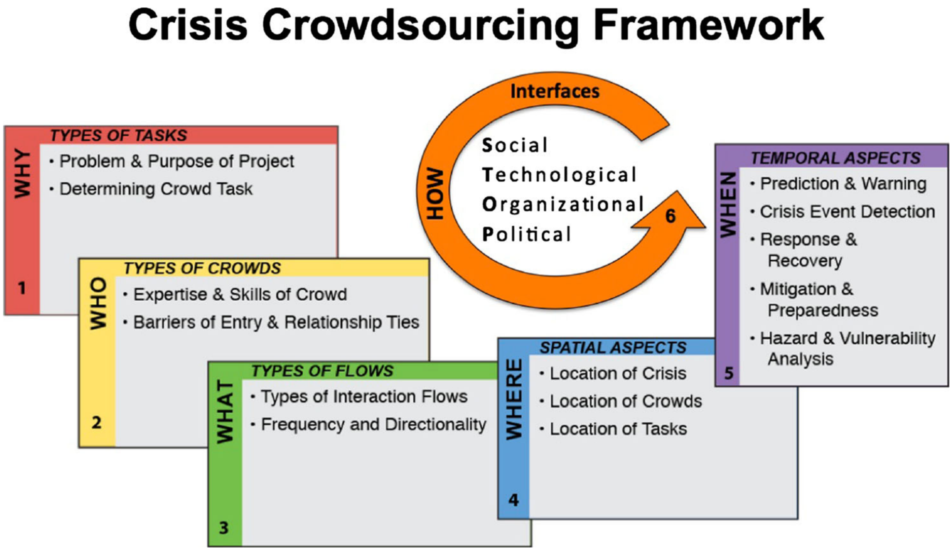


Figure 3. The crisis crowdsourcing framework and its six dimensions.

dimensions into an iterative workflow for strategically guiding the design of a crisis crowdsourcing project or system.

The six dimensions are as follows:

(1) Why – Identify the information problem to determine the crowd task needed;
(2) Who – Identify the types of crowds and expertise needed for the crowd task;
(3) What – Identify the interaction flows for engaging crowds;
(4) When – Identify temporal aspects in relation to the disaster lifecycle;
(5) Where – Identify spatial aspects of the crisis, crowds, and crowd tasks; and
(6) How – Identify social, technological, organizational, and policy (STOP) interfaces.

In the following six sub-sections, each dimension is explained with references to the vignettes to provide empirical examples.

5.1. Why – Identify information problem to determine crowd task

The first dimension (why) of the Crisis Crowdsourcing Framework focuses on identifying the information problem to determine what task to ask the crowd. The word "sourcing" typically refers to the request to perform a task. Rouse (2010) as well as Schenk and Guittard (2011) have identified "simple, moderate, complex, sophisticated, and creative tasks" that can be crowdsourced. Working directly with key stakeholders in the crisis domain can make it easier to identify the information problems and priorities that crowdsourcing can help solve. This section describes four common crowd

Table 1. Why – purpose of crowdsourcing project and associated crowd tasks.

WHY		
Crowd Task	**Problem and Purpose of Project**	**Description of Crowd Task Specific to Crises**
Sensing	Need empirical data of crisis effects in the impact zone to document and gain better situational awareness about the crisis	Detecting the observable effects of a crisis using the human senses in conjunction with metadata from machine-based sensors
Tagging	Too much unorganized data too tedious to process due to the lack of processing capacity through traditional methods	Categorizing a large amount of crisis data using folksonomic keywords or high-level terms from formal classification systems
Mapping	No baseline, current, and/or accurate map of the affected region existed before the crisis to compare with post-crisis data	Using professional and/or participatory geographic information systems to map the affected region through cartographic techniques
Curating	Difficult to find, manage, and access actionable, meaningful, and/or reliable crisis data to share to key stakeholders	Processing and managing a collection of crisis data through a set of activities like filtering, verifying, synthesizing, and exhibiting
...		

tasks that have emerged in the crisis domain. Table 1 summarizes the why dimension with examples of the following four crowd tasks presented in this section: (1) crowd-sensing, (2) crowd-tagging, (3) crowd-mapping, and (4) crowd-curating.

5.1.1. *Crowd-Sensing*

When a crisis suddenly occurs in a particular region, there tends to be a dearth of information from the affected region. Crowd-sensing is a way of collecting empirical eyewitness accounts needed from the affected population to document and gain better situational awareness about the effects of the crisis in the impact zone. Ubiquitous ICTs like social networking services and mobile devices are enabling crowds to be human sensors, giving them the ability to easily capture and share their on-the-ground observations quickly and widely. Goodchild (2007) describes “crowdsourced sensing” as detecting observable effects of a crisis using human senses in conjunction with metadata from computer-based sensors. Similarly, “participatory sensing” is a data collection method “where volunteers gather, analyze, and share local knowledge of their environment collected from stationary or portable sensors” (Bowser and Shanley 2013).

The DYFI website asks citizens who felt an earthquake to describe what they sensed and observed; whereas, the TED system uses an algorithm to sense or detect earthquakes based on significant spikes in seismic-related tweets. The Mission 4636 initiative also targeted earthquake-affected populations in Haiti encouraging them to text message their urgent needs to allow the international humanitarian response community to gain better situational awareness.

5.1.2. *Crowd-Tagging*

Often during disasters, too much disorganized data are generated and so it becomes too tedious to process the data through traditional methods. Asking crowds of people to tag or classify large amounts of data increases the information processing capacity needed to alleviate information management issues of organizing large datasets, such as social media feeds. Crowd-tagging could occur using folksonomic keywords generated and defined by the crowd (Vander Wal 2004). However, terms from formal classification systems and conceptual schemas may be preferred to better align with terminology used by key stakeholders involved in or that could benefit from the crowdsourced data. Tagging large datasets helps to index and organize distributed information objects, like public repositories maintained by multiple people (Star and Griesemer 1989; Bowker and Star 1991). Typically, tagging tasks are designed to be simple and easy to teach to a crowd; however, the quality of the tagging may largely depend on the crowd's familiarity with the type of data they are tagging.

Crowds were asked to tag the Mission 4636 messages for actionable crisis information, specifically categorizing messages related to missing persons, food and water shortages, and medical needs. The Ushahidi-Haiti platform began with simple categories targeting urgent needs, but the number of categories and sub-categories grew quickly to capture the nuances of crisis data from multiple online and offline sources (Meier and Munro 2010). The Standby Task Force often leverages Humanity Road's social media monitoring capabilities to handle the tagging and categorization of social media data in their SBTF deployments.

5.1.3. *Crowd-Mapping*

Maps are important communication mechanisms for coordinating and managing emergencies. One problem that may arise when a disaster occurs is not having a baseline, current, and/or accurate map of the affected region, making it difficult to accurately assess post-crisis data to direct response efforts. This is in part why "crisis mapping" has become a thriving field that has been at the forefront of harnessing and formalizing crowdsourcing in the crisis domain (Liu and Ziemke 2012; Ziemke 2012). Similar to what geographers call generating "volunteered geographic information" (Turner 2006; Goodchild 2007; Elwood 2008; Liu and Palen 2010, crowd-mapping is a task that typically consists of volunteers using professional (such as

ArcGIS) and/or participatory (such as OpenStreetMap) geographic information systems to create maps by drawing, tracing, and modifying geospatial features to spatially represent a region. Geotagging or geocoding is a form of crowd-mapping, where crowds spatially tag satellite imagery, for example, to visually mark certain features on a map.

The spontaneous crowd-mapping effort after the Haiti earthquake in using OpenStreetMap—an open-source mapping platform—resulted in a rapid, accurate post-earthquake map of Haiti that enabled the international humanitarian response community to better coordinate their relief efforts. Ushahidi is an open source crowd-mapping platform that allows anyone to submit and geotag crisis reports. Within SBTF, the Geo-location Team is tasked to find GPS coordinates for each crisis report and social media content they process, as well as keep an up-to-date Google Doc spreadsheet of all grid coordinates found by the SBTF volunteers for each deployment. Different geospatial tools and platforms (i.e., OpenStreetMap, Google Earth, ArcGIS, and map databases) are used to find location information associated with each report, as well as to keep track of all available maps of the affected area, including Lonely Planet™ tourist maps.

5.1.4. *Crowd-Curating*

The term 'curation' has frequently been used to characterize the information processing activities needed to manage and share big data, especially during disasters. Curatorial activities tend to consist of filtering, verifying, synthesizing, and exhibiting a curated collection of data. Pervasive ICTs like social media are increasing the crowd's capability to report data about a crisis. The emergency management community often views this as an information overload problem, particularly when harvesting or mining data from social media platforms. In a TED talk,[20] Erik Hersman—co-founder of Ushahidi—refers to this generation of data as "wasted crisis data" because there is not enough processing capacity to turn this "wasted crisis data" into "actionable information" useful for emergency responders.

During an emergency, curating crisis data means finding actionable crisis information and then sharing it in a meaningful way to key stakeholders. Crowd-curating is synonymous with the term "socially-distributed curation," which was introduced by Liu (2010; 2011; 2012) to describe the distributed and participatory nature of these activities that occur in parallel or in collaboration with others enabled through networking technologies. In contrast to "crowd-tagging" involving just one task or micro-task, "crowd-curating" involves a set of interrelated tasks or macro-tasks to address multiple aspects of information processing and management. Standby Task Force is well known for curating crisis data from social media and other online sources. Their crowdsourcing workflows were initially developed and publicly available as a Google Doc[21] to provide initial guidelines for new SBTF volunteers to get started. These workflows provided step-by-step instructions on how to filter, verify, synthesize, and display crisis data through crisis map mashups. However, the way SBTF volunteers carry out these crowd-curating tasks in practice is more situational and transparent on their Ning[22] social networking platform, Google spreadsheets, and Skype chats to adapt to the needs of the humanitarian organization requesting their service and the unique circumstances of the crisis event.

5.2. Who – Types of crowds to target for the task

The second dimension (who) of the Crisis Crowdsourcing Framework focuses on identifying the types of crowds and expertise to target for the crowd task. The word "crowd" typically implies an anonymous group of people or non-experts that have no defined set of expertise, skills, or credentials worth noting. However, people engaging in crowdsourcing efforts carry with them multiple roles, different expertise, and varying forms of trust in their relationships to each other. Meier (2011) offered the concept of "unbounded and bounded crowdsourcing" to point out how crowds can be bound by different types of expertise.

The following four crowd types were notable in the vignettes and are discussed in this section: (1) affected-populations, (2) diasporas, (3) social networks, and (4) digital volunteer communities. Table 2 summarizes the who dimension delineating each crowd's distinct skills and expertise, the barriers of entry to that crowd, and the relationship ties between the crowd members. Yet, it is worth noting that crowdsourcing efforts that involve open calls to the general public still bound or target crowds based on the media type used to distribute the open request. In other words, putting an open call online through a tweet on Twitter still only targets online crowds on Twitter who notice the tweet. Although only four crowd types are presented, there are many other crowds that converge during and around crises both online and offline (see Dynes 1970; Fritz and Mathewson 1957; Kendra and Wachtendorf 2003; Hughes et al. 2008). The key is leveraging the convergence of people and their motivation to want to participate in emergency management efforts.

5.2.1. *Affected populations*

Affected populations. are people directly in the impact zone or affected region when the crisis occurs. These survivors may or may not have pre-established ties to each other; however, sharing their local, timely, and direct experiential knowledge of the crisis effects can help themselves and others gain better situational awareness. Sharing the same spatio-temporal circumstance to the crisis is the type of ad hoc and transitory expertise that is often needed from event-based crowds for extracting place and time-sensitive information. Those directly impacted by the crisis are often the true first responders, self-organizing the provision of food, shelter, transportation, and other relief efforts (Fischer III 1998;

Table 2. Who – types of crowds and their expertise.

WHO		
Type of Crowds	**Skill and Expertise**	**Barrier of Entry and Relationship Ties**
Affected-Populations	Local, timely, and direct experiential information about the effects of the crisis in the impact zone during the emergency period	Bounded by people directly in the affected region during the impact of the crisis; Ad hoc, transitory role based on spatio-temporal circumstance of crisis; Loosely connected to each other by crisis
Diasporas	Socio-cultural tacit knowledge of affected population and region, such as knowing the language and local geographic places in affected region	Bounded by people displaced by a crisis or by having socio-cultural ties to the crisis-affected population and region; Closely connected to each other by their spatial and cultural connections
Social Networks	Varied backgrounds with unexpected and possibly fortuitous expertise relevant to the crisis that can quickly connect with other networks in one's social graph	Bounded by people with pre-existing connections with family, friends, colleagues, and other people that seem reliable and trusted; Connected to each other by social relationships
Digital Volunteer Communities	Community of digital volunteers with interests and capabilities in processing and managing crisis data	Bounded by people online with a shared interest and passion to volunteer for a cause; Fluid barriers of entry but may require training to participate
...		

Tierney et al. 2001; Clarke 2002; Kendra and Wachtendorf 2003). The affected population's role in a disaster has become quite important because of their increased capability to share crisis information in real-time through mobile and location-aware networking technologies (Boulos et al. 2011; Goodchild and Alan Glennon 2010; Hagar and Haythornthwaite 2005; Haklay et al. 2008; Liu and Palen 2010; Palen et al. 2009).

Both DYFI and TED target earthquake-affected populations using an online questionnaire and the Twitter platform to rapidly collect and then detect qualitative shaking intensities from seismic events. The first part of the Mission 4636 initiative also targeted earthquake-affected populations in Haiti, through local radio stations and by word-of-mouth, asking them to send SMS messages of their urgent needs. Digital volunteers from the Standby Task Force focus on monitoring social media for actionable information from affected populations to directly inform time-critical response efforts.

5.2.2. *Diasporas*

Diasporas. are cultural or ethnic populations displaced either some time ago or survivors recently displaced because of a disaster. Those with socio-cultural tacit knowledge of the affected population and region—such as knowing the language and local geography of the affected region—can be critical resources, especially for non-local emergency responders. Members of this crowd tend to be culturally connected with social trust built into their relationships with each other and the crisis event. They may be physically quite distant from each other, but they can quickly and remotely connect to each other through ubiquitous ICTs.

The second part of Mission 4636 targeted the Haitian diaspora with the time-critical task of translating Haitian-Kreyòl and French text messages into English. Their expertise of the local geography in Haiti also made them key resources for quickly deciphering names of places mentioned in the 4636 messages that were not easy to locate on current maps.

5.2.3. *Social networks*

Social networks. are people socially connected through familial, collegial, and/or convivial ties to each other. The level of trust they have with each other can subsequently affect how one interprets the quality and reliability of the data or service that these crowds produce. Crowdsourcing from social networks may facilitate quick connections to other networks in one's social graph, thus leveraging each other's trust, reputation, and social capital to seek additional help. Members of a social network tend to bring together a variety of backgrounds sometimes with unexpected expertise relevant to the crisis.

For example, Jeannine Lemaire—a SBTF volunteer working on USAID's first crowdsourcing deployment to geocode their Development Credit Authority data (Roberts et al. 2012)—tapped into her social network and stated in a presentation how "the true meaning of crowdsourcing is when I'm Skyping with my mom to get help with the Sri Lanka-based tasks our volunteers are having some trouble with," because her mom is from Sri Lanka.[23]

The Ushahidi-Haiti crisis map began largely from Patrick Meier tapping into his social network of friends and colleagues locally and abroad. Without knowing if his close friends conducting research in Port-au-Prince had survived the earthquake, he launched Ushahidi-Haiti and began reaching out to his friends and colleagues at The Fletcher School at Tufts University, where he was conducting his doctoral graduate studies. He brought together over 100 students volunteering their time and resources to learn how to monitor social and traditional media for actionable content that could be mapped. As Ushahidi-Haiti gained more attention in the mainstream media, the crowd-mapping and crowd-curating effort went viral, drawing in other volunteers from around the world.

5.2.4. *Digital volunteer communities*

Digital volunteer communities. often emerge after crises and sometimes formalize into virtual volunteer organizations. In the crisis mapping community, the phrases "volunteer & technical community" and "volunteer technology community" (or VTC for short) have increasingly been used to reference these ICT-enabled and volunteer-based communities that apply and leverage their technical skills in collecting, processing, and managing data in support of response efforts for disasters and humanitarian crises (Capelo et al. 2012; Harvard Humanitarian Initiative 2011). Members of these crowds tend to use decentralized approaches and open source technologies to reduce collaboration costs and produce open data intended to improve humanitarian relief efforts. These virtual communities tend to have fluid barriers of entry but are bounded by a shared interest and common passion to volunteer for a cause. Members of these volunteer communities are sometimes experts themselves, or they may require training before they are officially volunteers in that community.

Immediately after Typhoon Bopha/Pablo, UNOCHA used the DHNetwork to target and activate SBTF and Humanity Road, since these VTCs have established their expertise in collecting and geotagging social media to inform crisis response efforts. DHNetwork is a network of VTCs and can source other virtual communities, like Geeks Without Bounds for programming expertise, Statistics Without Borders for statistical analysis expertise, and GISCorps for geospatial analysis expertise.

Some of these virtual communities and organizations have existed for a long time. For example GISCorps[24] was established in 2003 as a program associated with the Urban and Regional Information Systems Association to provide immediate online and offline geospatial services during emergencies. Shoreh Elhami—co-founder of GISCorps and also GIS Director at the Delaware County Auditor's GIS Division—explained in an email interview that GISCorps offers approximately 2,800 registered geo-experts distributed across 94 countries.

5.3. What – Interaction flows for engaging crowds

The third dimension (what) of the Crisis Crowdsourcing Framework focuses on identifying the interaction flows for engaging crowds in terms of directionality and frequency. Typical characterizations of "crowd-sourcing" tend to assume an active, one-way flow of directly requesting data or services from a crowd. However, in practice, a complex set of interaction flows and engagement strategies are used among the various crowdsourcing actors. This section describes five common types of interaction flows for engaging crowds. Table 3 summarizes the what dimension by explaining the following five interaction flows: (1) parallel sourcing, (2) iterative sourcing, (3) crowd-seeding, (4) crowd-feeding, and (5) crowd-harvesting.

5.3.1. *Parallel sourcing*

In computer science, researchers tend to analyze crowdsourcing systems by experimenting with parallel and iterative models of human computation to test

Table 3. What – types of information flows and engagement strategies.

WHAT	
Interaction Flows	**Types of Interaction Flows and Engagement Strategies**
Parallel Sourcing	Each crowd worker performs the same task independently to generate a collective output that still allows analysis of differences between crowds
Iterative Sourcing	Each crowd worker iteratively improves the work of previous workers thus facilitating a sequential improvement but could propagate error more quickly
Crowd-Seeding	Active, one-way request that strategically targets certain crowds to engage with as opposed to an open call to an undefined crowd
Crowd-Feeding	Active, two-way feedback loop where information from or tasks conducted by the crowd are fed or shared back to the crowd in a meaningful way
Crowd-Harvesting	Passive, one-way gathering of data that harvests or mines the crowd's information or services sometimes without their direct knowledge or consent
…	

various engagement strategies (Little et al. 2010; Maisonneuve and Chopard 2012). Parallel sourcing is when each member of a crowd performs the same task independently or in parallel with others, and then an aggregation function is used to generate a collective output. Although the parallel approach does not require mutually dependent resources and processes, it tends to be a part of a larger process that is dependent on the collection of these data. The parallel model has the potential to collect a broader range of data than the iterative model because it reduces the likelihood of each crowd worker to be influenced too narrowly on the work of previous crowds. The parallel model also makes it easier to consistently analyze and compare the quality of the crowdsourced data within and between different types of crowds.

DYFI and TED use the parallel sourcing approach to collect independent reports of seismic activity from earthquake-affected crowds, which are then aggregated to rapidly detect earthquakes and inform other USGS earthquake products. The process of translating, geocoding, and categorizing the Mission 4,636 messages were largely conducted using the parallel sourcing model. Typically only one volunteer translated, geocoded, and categorized a message; in other words, other volunteers did not process that same message.

5.3.2. *Iterative sourcing*

In contrast, iterative sourcing involves a series of crowd workers iteratively improving the work of previous workers, thus facilitating a sequential improvement of the crowdsourced data that is collectively and iteratively produced. This approach does not require each worker to start from scratch, but rather to build on top of another's work thus creating mutual interdependencies between the crowds, information, and resources. Although data quality can be improved by involving different crowds over time, this approach can also propagate both error and accuracy quickly. For example, having non-expert crowds and then expert crowds conducting the crowd task can help to determine what sequential ordering facilitates higher quality crowdsourced data, in terms of accuracy, efficiency, reliability, and timeliness.

The OpenStreetMap platform primarily engenders iterative sourcing, where any edit submitted to the OSM map is immediately visible to the public to allow additional edits from other mappers. A different form of iterative sourcing occurs with the SBTF teams and their associated workflows. Although SBTF volunteers use the parallel sourcing approach to validate individual crisis reports, they primarily engage in iterative sourcing within each SBTF team as well as across the five SBTF teams by iteratively curating the crisis reports.

5.3.3. *Crowd-Seeding*

Crowd-seeding. is a strategic form of crowd-sourcing involving an active, one-way request that pre-identifies certain people in a crowd to engage with initially and sometimes empowering them with the tools to do so. Van der Windt (2012) coined the term "crowd-seeding" as an approach that "combines the innovations of crowdsourcing with standard principles of survey research and statistical analysis" to limit participation to certain members within a crowd. Targeting certain members in a crowd or certain types of crowds can facilitate a trusted, localized, and controllable crowdsourcing effort.

The immediate need for translating and geocoding the Mission 4,636 messages quickly led to identifying the Haitian diaspora as the key crowd to initially target through crowd-seeding. In response to Typhoon Bopha/Pablo, UNOCHA also used the crowd-seeding approach to target VTCs they had already worked with who were familiar with monitoring and mapping social media data.

5.3.4. *Crowd-Feeding*

Crowd-feeding. moves beyond one-way interaction flows to creating an active, two-way feedback loop with the crowd typically through networking technologies. One form of crowd-feeding occurs when data generated or tasks conducted by the crowd are then fed or shared back to the crowd. Meier introduced this term in a blog post[25] to explain how the Ushahidi alert feature facilitates crowd-feeding by allowing anyone to setup email push alerts of Ushahidi crisis reports in a particular geographic region. Similarly, the creation of Ushahidi categories like 'Need Transport' and 'Have Transportation' bridges the coordination work "between those who need help and those who wish to help." These folksonomic categories created in Ushahidi facilitated the coordination of mutual aid by matching the crowd's needs with their own available resources, states Gregory Asmolov[26] co-founder of the Ushahidi 2010 Russian Fires crisis map containing these categories.

Another way of providing feedback to the crowd is by processing the crowdsourced data and sharing it back to the crowd in a meaningful way. Over the past decade, DYFI has facilitated interactions between the scientists of a government agency and the community that they serve by providing a two-way flow of post-earthquake information. DYFI reports provide USGS with high-resolution data of shaking intensities integrated into other official USGS hazard products, while the DYFI website is a platform for earthquake-affected populations to receive instant feedback to validate their ground shaking experiences through official earthquake products.

The crowdsourcing that occurs during crisis situations are typically volunteer-based; however, monetary incentives and other reward mechanisms could be used to motivate and engage crowds to continue participating. When the processing of the Mission 4,636 messages was transferred from digital volunteers to SamaSource's paid Haitian workers, it gave unemployed Haitian women and impoverished youth in Haiti the opportunity to earn money through digital employment. Many crowdsourcing systems and citizen science applications are beginning to use gamification features (e.g., leaderboard and achievements) to also offer non-monetary rewards.

5.3.5. *Crowd-Harvesting*

All the previous interaction flows are direct requests to a crowd to perform a task. Crowd-harvesting is a passive, one-way information flow that does not direct the crowd to perform a task, but rather harvests or mines the crowd's data or services sometimes without their direct knowledge or consent. Many projects use data mining techniques to passively collect and process social media data from the online crowd by utilizing existing networking platforms to collect this crowdsourced data. Thus, it is important to consider the differences in collaboration between voluntary and involuntary sharing of data, as well as between informed and uninformed consent of using data from online crowds. Such differences largely depends on the Terms of Service and Use Agreements defined by each online service provider.

TED is set up to automatically crowd-harvest a large number of earthquake-related tweets from Twitter, which are then used to trigger the TED real-time earthquake detection system. However, these tweets were passively sourced in that Twitter users were not actively requested to tweet when they felt an earthquake. However, Twitter's Terms of Service[27] license agreement requires all Twitter users to consent to authorizing Twitter to make a user's tweets "available to the rest of the world and to let others do the same." Similarly, VTCs like SBTF crowd-harvest social media data manually in conjunction with other social media analysis tools. Crowd-harvesting is typically conducted first in order to facilitate other crowd tasks like crowd-curating—as with SBTF's response to the Typhoon Bopha/Pablo in the Philippines.

5.4. When – Temporal aspects in relation to the disaster management lifecycle

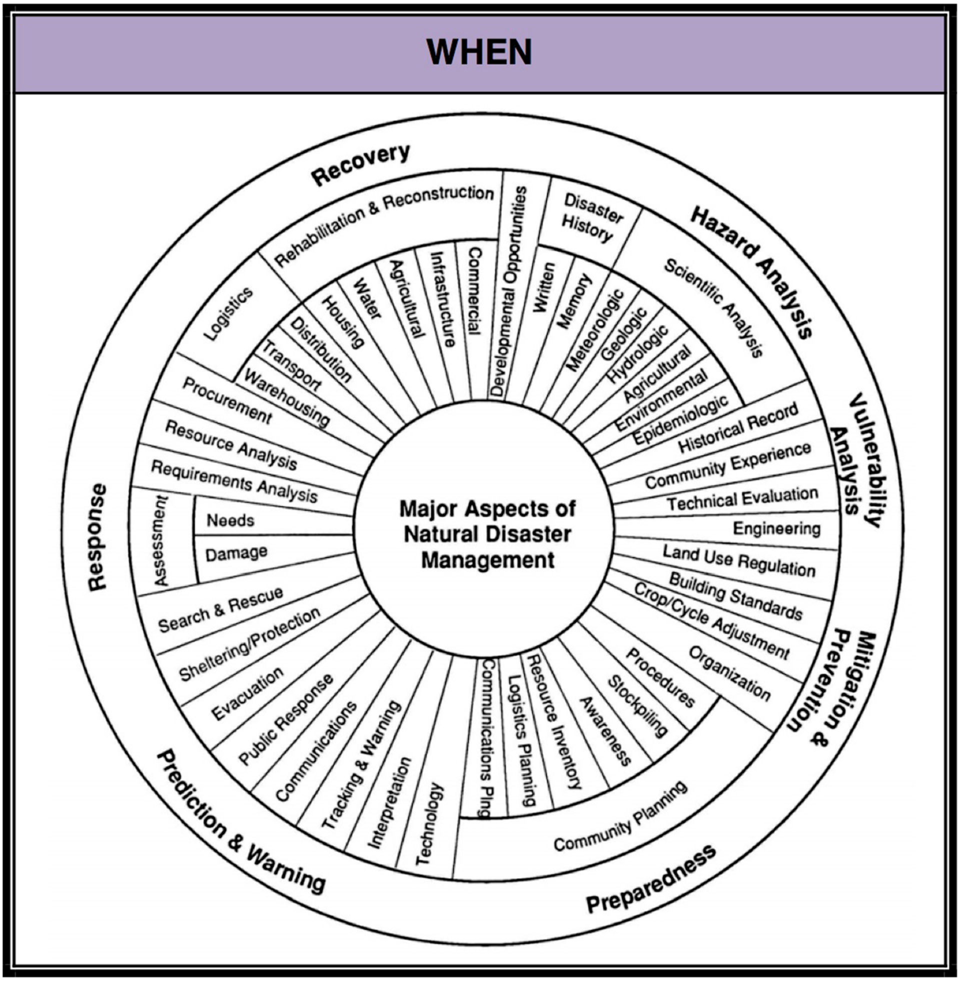
The fourth dimension (when) of the Crisis Crowdsourcing Framework focuses on identifying the temporal aspects of the crowdsourcing project in relation to the disaster management lifecycle. Crowdsourcing is typically used to address information gathering and management issues during a specific disaster phase, for the entire disaster lifecycle of a crisis event, or across multiple crisis events. Roche et al. (2011) as well as Vivacqua and Borges (2012) offer guidelines for designing and analyzing crowdsourcing initiatives and systems that correspond with the different disaster phases. Table 4 contains a figure that summarizes the when dimension delineating the major aspects of disaster management across the different disaster phases (i.e., prediction and warning, response, recovery, mitigation and prevention, preparedness, as well as hazard and vulnerability analyses phases). Each crisis crowdsourcing project moves through the disaster management lifecycle differently depending on the type of hazard, its impact, as well as the frequency and longevity of the crowdsourcing project.

5.4.1. *Detecting crisis events for hazard and vulnerability analysis*

Crowdsourcing can be used to detect crisis events, but this largely depends on the type of hazard. Meteorologists can typically forecast hurricanes days in advance; whereas, earthquakes cannot be predicted, only detected with seismic instruments. People in an earthquake-affected region can be valuable sensors for detecting shaking intensities from seismic events, especially in sparsely instrumented regions.

The USGS TED system crowd-harvests Twitter data in real-time to detect earthquakes on average about a minute after the origin time of an earthquake, which is often faster than the network of seismic sensors. DYFI reports may also arrive before seismograms from seismic stations are processed. TED alerts and DYFI reports provide seismologists preliminary qualitative data of shaking experiences to augment their traditional methods. Instrumentally derived seismic data can often take between 2 to 20 minutes for seismologists to analyze. Crowd-sensed data can be used to rapidly detect crisis events, as well as augment official hazard products and services. When these data are collected over long periods of time across multiple crisis events, such time series data can improve hazard and vulnerability assessments and the timeliness for sharing these hazard products to key stakeholders and the wider public.

Table 4. When – temporal aspects in relation to the disaster management lifecycle (figure adapted from Schramm and Hansen[39] to provide a more comprehensive account of the disaster lifecycle beyond listing the typical four disaster phases of preparedness, response, recovery, and mitigation).



5.4.2. *Immediate activation in the response, recovery, and preparedness phases*

Spontaneous crisis crowdsourcing efforts tend to emerge immediately after the impact of a hazard to inform time-critical response activities, such as search and rescue efforts and other urgent needs from the affected population. Many crowd-tagging and crowd-mapping efforts are intended to produce damage assessments that can improve the logistics of aid distribution. Some crisis crowdsourcing efforts continue beyond the immediate response phase to also inform long-term recovery and preparedness efforts, such as debris cleanup and rebuilding critical infrastructures. However, crowdsourcing efforts for slow onset hazards, like droughts and political conflicts, tend to occur in the recovery and preparedness phases.

The spontaneous crowdsourcing efforts that generated the OSM Haiti map and the Ushahidi-Haiti crisis map resulted in maps used for search and rescue efforts and for generating damage assessments of the affected region. According to HOT,[28] the OSM Haiti map became “the default basemap for responding organizations such as Search and Rescue teams, Humanitarian mapping NGOs like MapAction and iMMAP, the United Nations, and the World Bank.” SBTF and HOT are often immediately activated after major disasters via the DHNetwork to provide rapid crowd-mapping services for hazards like typhoons and earthquakes. They also respond to slow onset crises, like political election violence and mapping informal settlements due to droughts, during the recovery phases of these humanitarian crises. These VTCs also engage in crowd-mapping efforts during the preparedness and mitigation phases to facilitate capacity building and strengthen community resilience. Some crowd-mapping deployments focus on mapping critical infrastructure for earthquake and flood preparedness. There is also a growing interest to remotely participate in virtual exercises, simulating different and multiple disaster phases, to train and refine crowdsourcing efforts during non-emergency times.

5.4.3. *Iteratively across multiple crisis events*

In the process of formalizing the spontaneous crowdsourcing efforts that emerged after the Haiti earthquake, interfaces or interaction mechanisms have been developed and refined to sustain these crisis crowdsourcing efforts over time across multiple crisis events. They are designed to reduce the complexity of coordinating distributed and spontaneous volunteers across multiple crisis events or even simultaneous crisis events. They are also designed with the purpose of reusing them for future crises to refine and improve crowdsourcing efforts.

For example, a large number of jobs are listed within the OSM Tasking Manager, showing numerous crowd-mapping projects since its inception. The Ushahidi crowd-mapping platform and CrowdMap cloud service have been used extensively over the years and deployed for various crisis events. The DHNetwork is an interface that allows humanitarian organizations to quickly and repeatedly activate VTCs like SBTF for multiple crisis events. DYFI and TED are real-time web systems setup to detect seismic events around the world. Sometimes there are earthquakes that may occur simultaneously nearby each other or in other parts of the world. Spatiotemporal inputs and trends improve the accuracy of these real-time monitoring systems.

5.5. Where – Spatial aspects of the crisis, crowds, and crowd tasks

The fifth dimension (where) of the Crisis Crowdsourcing Framework focuses on identifying the spatial aspects of the crowdsourcing project. Table 5 summarizes the where dimension to distinguish between the location of the crisis, the places where crowdsourcing actors reside, and the medium in which the crowd tasks occurs.

5.5.1. *Location of crises*

The location and spatial extent of a crisis will vary depending on the type of hazard and its impact on the affected region. For example, the impact of earthquakes is largely dependent on the geologic features of that region, whereas hurricanes and other extreme storms may affect a much larger region depending on where they make landfall and their paths onto the mainland. Maps are critical resources for gaining situational awareness of the impact zone and its periphery when coordinating with stakeholders and crowdsourcing actors. Therefore, it is no surprise that crisis mapping, in general, has become an important part of emergency management.

HIU's Imagery to the Crowd workflow coordinated through the OSM Tasking Manager must pre-identify the affected region to import the appropriate satellite imagery into the OSM Tasking Manager to allow crowd-mapping to occur. The TED real-time detection system automatically geocodes each tweet to detect the nearest city where earthquake-related tweets originated. Thus, the location of the crisis could be a parameter of the

Table 5. Where - spatial aspects of the crisis, crowds, and tasks.

WHERE	
Location of Crises	Impact zone and periphery of crisis, which may vary depending on hazard type. May span multiple regions affected by certain hazards over time.
Location of Crowds	Depends on type of crowd; affected-populations are in the impact zone. Crowds could work collocated while others tend to work remotely online.
Location of Tasks	Depends on the type of crowd task. Many projects are accessible online via a website. Some are mobile applications accessible on portable devices. Other tasks may involve participating at a physical event or exhibit.

crowdsourcing system or even the output in terms of using crowdsourced data to determine the location of the crisis.

5.5.2. *Location of crowds*

The location of the crowds will largely depend on the type of crowds that are targeted. Affected populations are event-based crowds in the impact zone. Typically, these crowds use ICTs, like mobile phones and other locative media, to engage in crowd-sensing physically from the affected region. However, many of the crisis crowdsourcing projects taking place in the digital age consist of remote crowds conducting their work in a virtual manner using networking technologies.

HOT works both remotely with the global OSM community to immediately respond to disasters, and physically in different countries to train locals and humanitarian actors on how to use OSM to create a sustainable mapping community. However, many of the VTCs, like SBTF and Humanity Road, have formed virtual organizations or communities with digital volunteers, thus providing around-the-clock, around-the-world coverage across several time zones. The DHNetwork is leveraging this innovative form of global coordination by creating a consortium of VTCs on-call for the next disaster.

5.5.3. *Location of tasks*

The location of the crowd tasks means distinguishing the various venues in which the crowd task could occur. Although many of the crowd tasks take place remotely in virtual platforms (e.g., website, mobile application, Google Doc spreadsheets, etc.), remote crowd work could still be conducted through colocation. For example, the crowd tasks involved with Ushahidi-Haiti initially occurred in Patrick Meier's living room, but then moved to a Situation Room at Tufts University before it became a global online effort. A variety of online and offline tools may be used to complete a crowd task, thus it is important to consider the different centralized (one-to-many), decentralized (many-to-many and many-to-one), and meshed (one-to-one) communication platforms that could be leveraged.

SBTF uses free cloud computing tools (i.e., Google Groups, Google Docs and Forms, and Skype Public Chat) to more easily coordinate with each other and across the five SBTF teams. The location of their tasks can vary, since their activities involve translation, surfing the web, processing incoming SMS messages, creating incident reports, and carefully geocoding each incident. HIU's MapGive website centralizes the crowd-mapping task via the OSM open source mapping platform and the OSM Tasking Manager to authorize and constrain the crowd-mapping task to the virtual confines defined by the NextView's Imagery Sharing policy agreement.

5.6. How – Social, Technological, Organizational, & Policy (STOP) interfaces

The sixth dimension (how) of the Crisis Crowdsourcing Framework focuses on identifying the Social, Technological, Organizational, and Policy (STOP) interfaces that need to be addressed to operationalize crowdsourcing in the emergency management environment. Table 6 summarizes the how dimension by describing the key interfaces where innovation can occur and where change may be needed to enable crisis crowdsourcing.

5.6.1. *Social interface*

The social interface encompasses the socio-cultural norms, values, beliefs, and practices associated with crowdsourcing. The phenomenon of public engagement and volunteerism during crises is not new, but new forms of ICT-enabled public participation have raised questions and concerns about how data from the general public can be trusted. In recognizing the need to re-align differences in data sharing values and practices, "open data" initiatives and practices have emerged to encourage data sharing between governments, organizations, and the public.

Another critical aspect of the social interface is recognizing and leveraging the ways in which crowdsourcing has become mainstreamed and professionalized officially and informally. Various networks of experts and initiatives have been established specifically around the theme of crisis mapping, crowdsourcing, and social media use in emergency management.

In March 2014, the Social Media Working Group Act of 2014 authorizes the U.S. Department of Homeland Security (DHS) to officially establish and expand "both the membership and influence of the DHS's Virtual Social Media

Table 6. How - Social, Technological, Organizational, and Policy (STOP) interfaces.

HOW	
STOP Interfaces	**Explanation of Each STOP Interface**
Social	Socio-cultural norms, values, beliefs, practices, and relationships with other key stakeholders or actors involved in the project
Technological	Development of a technical system, tool, or artifact to efficiently, reliably, robustly enable the crowdsourcing effort
Organizational	Organizational structures, conceptual schemas, standard operating protocols, and allocation of resources
Policy	Policies and regulations on engaging with crowds and managing crowd data

Working Group (VSMWG). VSMWG provides recommendations to the emergency preparedness, response and homeland security communities on the safe and sustainable use of social media technologies before, during and after emergencies. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) Programme has organized three international expert meetings on "Space-based information for Crowdsource Mapping" since 2011.[29]

In academia, crowdsourcing has become a hot topic for informatics courses, a recurring special issue for journals in various fields, and a standard track at conferences and workshops. At the same time, various virtual exercises like Exercise 24, field experiments like the Naval Postgraduate School's Joint Interagency Field Experimentation (JIFX) and Research & Experimentation for Local & International Emergency & First-Responders (RELIEF) quarterly events, and online trainings like TechChange's "Tech Tools and Skills for Emergency Management" course have mainstreamed and professionalized crisis crowdsourcing.

5.6.2. *Technological interface*

The technological interface involves the development of a technical system, tool, or artifact. Human-centered design techniques and agile development methods may be needed to iteratively refine its design. Testing for efficiency, reliability, and robustness is also critical for ensuring that the technical aspect of the system is scalable enough to handle large crowds of users, and to rapidly process and store large amounts of unstructured data generated from the crowd. Crowdsourcing systems tend to exist online through websites and cloud computing services, but mobile and location-aware devices may also be used.

The translating, geocoding, and categorizing of the Mission 4,636 messages were primarily conducted through the commercial crowdsourcing platform called CrowdFlower, a well-tested system at the time of its use after the Haiti earthquake. Yet, open-source platforms like Ushahidi allow anyone to set up an Ushahidi instance and continually refine and adapt the platform for various types of events that could benefit from crowd-mapping. However, digital volunteer communities like SBTF tend to use a myriad of simple-to-use and easy-to-access ICTs like Google Docs and Skype chats, sometimes adapting their crowdsourcing practices to align with the capabilities and constraints of the technologies they are familiar with using.

5.6.3. *Organizational interface*

The organizational interface focuses on recognizing when organizational structures, standard operating protocols, conceptual schemas, and allocation of resources are in alignment or in conflict when agencies, organizations, and publics try to collaborate and coordinate during disasters. Crowdsourcing can augment existing workflows, but formalities need to be considered to legitimatize its integration into official procedures. The organizational interface tends to be where crowdsourcing can be disruptive and challenge traditional structures and protocols, but it is oftentimes the place where innovation is needed.

For example, the Digital Humanitarian Network is an organizational interface to allow humanitarian organizations like UNOCHA directly engage with established-VTCs like HOT, SBTF, and Humanity Road. DHNetwork centralizes these requests through a formal activation protocol that aligns the needs of the humanitarian community to the VTCs with the relevant skills and services that can address this need. At the same time, VTCs like SBTF have made considerable progress in formalizing their own activation protocols and crowdsourcing workflows to legitimize their expertise in crowd-mapping and social media monitoring during disasters.

5.6.4. *Policy interface*

The policy interface focuses on the legal policies and regulations on engaging with crowds and managing crowd data that may be enabling or hindering a crowdsourcing project. Although engaging with the public is not a new practice, engaging online crowds and their data has raised many flags. For example, there are restrictions and protections about collecting and storing personally identifiable information (PII), especially from social media platforms. However, determining what is sensitive or personal information in the digital age is not straightforward. More importantly, it is unclear where this type of sensitive information may ultimately be stored, shared, and managed.

There are also binding legal obligations around sharing large, expensive, or classified datasets. Licensing agreements may need to be revisited and altered to legally share data to facilitate crowdsourcing, as in the case with HIU's Imagery to the Crowd workflow. Data sharing practices can vary substantially between different entities for each crisis event. The Haiti earthquake was so catastrophic that it was to the benefit of all stakeholders to share as much data as they could. For smaller crises or during non-emergency times, data are typically not freely shared and restrictions may be applied on how and when those data can be used. MapGive is an innovative example of using a technological interface to incorporate organizational and policy interfaces to reduce the articulation work needed to enable rapid crowd-mapping.

6. Applying the crisis crowdsourcing framework

An example is presented to understand how to apply the Crisis Crowdsourcing Framework. The framework guided the development of a crisis crowdsourcing project for the U.S. Geological Survey called "iCoast – Did the Coast Change?" (Liu et al. 2014). The framework provided guidelines for articulating the key dimensions and approaches for engaging crowds in cooperative work related to coastal change after extreme storms. Some of the implications for applying the framework are discussed to inform the design of this crisis crowdsourcing system, especially at a Federal science agency, where part of the USGS mission is to develop and apply hazard science research to help protect the safety, security, and economic well-being of the Nation.

USGS oceanographers and geologists have been investigating geomorphic processes that affect U.S. coastlines and the natural ecosystems that protect coastal communities. Beaches, dunes, barrier islands, wetlands, and bluffs are natural coastal barriers that provide the first line of defense to storm impacts and are critical factors for assessing coastal vulnerability after hurricanes and other extreme storms make landfall. The USGS National Assessment of Hurricane-Induced Coastal Erosion Hazards project[30] provides extensive reports and offers interactive online maps[31] to geospatially identify coastal areas most vulnerable to storm impacts and to better direct response and recovery resources before and in the immediate aftermath of storms for emergency responders, coastal managers, coastal residents, and other relevant stakeholders. These predictive models can also inform recovery and mitigation efforts, as well as future redevelopment plans to decrease coastal vulnerability and strengthen coastal resilience.

The inspiration for iCoast was driven by the progress of earlier USGS citizen-based science websites for earthquakes,[32] landslides,[33] and volcanoes,[34] as well as the development of Tomnod and MapMill for providing situational awareness to the emergency management community. Tomnod[35] is a crowd-mapping or geotagging system that asks online crowds to spatially annotate post-disaster satellite imagery to crowdsource damage assessments (Barrington et al. 2011). After Hurricane Sandy, HOT adapted the open-source rating system called MapMill[36] (Warren 2010) to ask crowds online to conduct remote damage assessments using Civil Air Patrol aerial photographs (Munro et al. 2013).

6.1. Why: Crowd-tagging aerial imagery to ground truth prediction models

The USGS has collected over 140,000 oblique aerial photographs of the coast before and after 24 extreme storms since 1995. After Hurricane Sandy in 2012, over 9,000 aerial photographs of the US eastern coast were taken across six states a week after the storm. Typically, the USGS creates a handful of pre- and post-storm aerial photograph pairs to compare to high-resolution dune elevations derived from lidar data, which are typically used to improve models that predict the likely interactions between storm surge and coastal features during hurricanes to identify areas vulnerable to storm damage (Plant and Stockdon 2012).

However, USGS scientists lack the information processing capacity and personnel to manually analyze the thousands of images collected after each storm. Image analysis software cannot automatically identify the geomorphic changes to the natural landscape and the damages to the built environment that are depicted in these photographs. Human perception and local knowledge are still needed to detect geomorphic coastal changes from oblique aerial imagery.

"iCoast – Did the Coast Change?" is a crowd-tagging web application that allows digital volunteers to compare before and after photographs of the coast and identify changes that result from extreme storms. The first project in iCoast focuses on coastal changes after Hurricane Sandy. This crowdsourcing system is designed and configured for USGS coastal scientists to validate USGS predictive models of coastal change—probabilities of beach and dune erosion, overwash, and inundation along the coast geospatially shown on interactive maps (Figure 4)—and to better gauge the accuracy of pre-storm coastal vulnerability assessments (Plant and Stockdon 2012; Doran et al. 2012; Stockdon et al. 2012; Stockdon et al. 2013). Currently, these predictive models—which are widely used in the emergency management community for locating areas of potential vulnerability to incoming storms—are based solely on pre-storm beach morphology as determined by high-resolution elevation data, and predicted wave behavior derived from the National Oceanic and Atmospheric Administration's

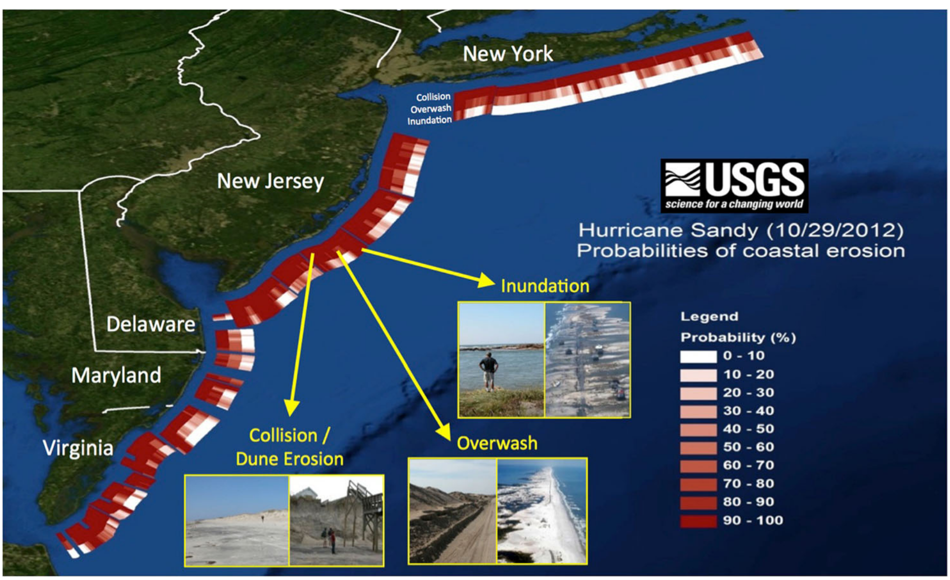


Figure 4. U.S. geological survey coastal change prediction models showing probabilities of coastal erosion along the new jersey coast generated prior to the landfall of hurricane sandy in 2012.

(NOAA) parameters of the approaching storm. The post-storm observations provided by volunteers using iCoast will allow USGS scientists to determine the accuracy of these predictive models for future applications.

6.2. Who: Targeting crowds with coastal expertise

Since iCoast focuses on coastal changes after extreme storms, crowds with coastal expertise will primarily be targeted. The initial iCoast users have been USGS oceanographers and geologists conducting research in coastal science, as well as local marine science professors and students at universities and colleges nearby in St. Petersburg, Florida. Coastal managers, planners, and engineers at local, state, and Federal agencies will also be targeted, particularly coastal practitioners from NOAA, the U.S. Fish and Wildlife Service (USFWS), and the U.S. Army Corps of Engineers (USACE). Coastal residents will also be targeted, especially those that were affected by Hurricane Sandy along the eastern coast of the U.S. At the same time, crowds with little or no coastal expertise, such as digital volunteers from the Standby Task Force as well as the general public online, will be targeted through social media platforms. The iCoast system requires users to login and select the type of crowd they belong to (i.e., coastal and marine scientist, coastal planner or manager, coastal resident, watersport enthusiast, marine science student, emergency responder, digital crisis volunteer, interested public, or other) and indicate any coastal expertise they may have.

6.3. What: Strategic interaction flows for engaging crowds in coastal change

Currently, the iCoast system only supports the parallel sourcing approach to consistently analyze the differences in annotation quality within a certain crowd type as well as between different crowd types. Analyzing such data will result in determining a threshold for the number of independent contributions needed to reach the quality and accuracy of annotations comparable to annotations from coastal science experts. The parallel model also facilitates a broader range of annotations to uncover other keywords or tags that could be included in future iCoast projects. The iterative sourcing approach may be implemented later using a small set of photographs to see how many non-expert volunteers are needed to reach the same quality and accuracy as annotations from coastal science experts.

Initially, the crowd-seeding approach was employed to focus on a bounded crowd of USGS oceanographers and geologists conducting coastal change research to elicit design requirements for iCoast to ensure that the scientists can use iCoast to validate their predictive models. Then, crowds with a broader set of coastal expertise (e.g., coastal managers and planners, coastal residents, marine science students, etc.) were targeted. Crowd-feeding is also being employed by allowing iCoast users see how their annotations compare with other users or crowd types, and how their annotations are improving USGS predictive models. Gamification features have been implemented to share iCoast data back to the users to motivate them to continue participating.

USGS coastal scientists have started to manually crowd-harvest social media photographs in an ad hoc way to ground truth their pre-storm assessments. First person accounts with photographic evidence of coastal changes that occurred during a storm are becoming more readily available online through photo and video sharing websites like Flickr, Instagram, and YouTube. A more comprehensive and automated crowd-harvesting solution may be developed to produce an additional source of data to ground truth their pre-storm assessments immediately after extreme storms. Social media streams and other public coastal imagery from live traffic web cameras could also be developed to harvest real-time, geo-referenced imagery of the coast.

6.4. When: Merging geologic time with multiple disaster phases

iCoast merges geologic time with the disaster lifecycle to visually detect and analyze coastal changes after extreme storms using multi-temporal imagery. This crowdsourcing system has been designed to also be reusable for past and future storms. The pre- and post-storm aerial surveys are not always consistently collected and may have been taken at different tidal levels. For the first project in iCoast, the photos were taken a week after Hurricane Sandy made landfall; however, the pre-storm photos were taken three years before with some photos from 2011 after Hurricane Irene. Since USGS works in geologic time across multiple time scales, the agency is uniquely positioned to apply these slow geologic processes to the collective experience of society to predict hazards.

The goal of iCoast is to improve the predictive models of coastal erosion, which indirectly informs evacuation, response, recovery, and mitigation efforts. However, iCoast directly informs the hazard and vulnerability analysis phases by scientifically documenting coastal hazards from a geologic and environmental perspective. The coastal aerial photographs document the damage to coastal engineering structures, as well as how coastal communities responded to the storm. Land use regulation and building standards that have been implemented along the U.S. coastline could be gleaned from these images. Also, iCoast is designed to offer on-demand hazard education and awareness regarding coastal vulnerability to promote risk-wise behavior and more informed decision-making around coastal planning and management.

6.5. Where: From storm-affected coastlines to globally online

The first iteration of iCoast focuses on the coasts of six US States—namely New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina—affected by Hurricane Sandy in 2012. However, the iCoast system has been designed to import aerial imagery from past and future hurricane-affected coasts in the U.S. primarily along the Atlantic and Gulf coasts.

The location of the crowds that may be potential users of iCoast converges in certain regions, but is still quite distributed around the world. The initial users of iCoast are scientists at the USGS Coastal and Marine Science Center in St. Petersburg, Florida. Other users, particularly coastal and marine scientists, will be sourced locally in the Tampa Bay area of Florida. Additionally, coastal communities from the six U.S. States affected by Hurricane Sandy will be targeted, as well as coastal managers, planners, and engineers located at established coastal centers and Federal agencies around the U.S. and other parts of the world. The general online public and digital volunteers from VTCs, like Standby Task Force, are located around the world but will be targeted using social media platforms.

The location of the crowd-tagging task primarily takes place remotely online through the iCoast website accessible via the Internet; however, there are various venues in which the iCoast system has been promoted and demonstrated. The initial use of iCoast took place at the offices of USGS coastal scientists to understand the environment in which these scientists conduct their cooperative work around coastal change research. The iCoast system was also presented in marine science classes at nearby colleges and universities to obtain early feedback on the system. Demonstrations of the iCoast system were also conducted at recent technology and geography conferences to attract other types of crowds that may not have coastal expertise. Configuring a simplified version of iCoast as part of an interactive exhibit on hurricanes and coastal hazards at local science museums and aquariums may also be developed.

6.6. How: STOP interfaces that enable and hinder iCoast

For the social interface, it was critical to develop trusted relationships with USGS coastal scientists willing to incorporate crowdsourcing into their work practice to validate their predictive models. The USGS has engaged in many citizen science projects, with the early establishment of "Did You Feel It?" over a decade ago. As a federal science agency, the USGS has a long history of involving the public and legitimating citizens as valuable human sensors. This has allowed many to argue that crowdsourcing is not new and has been quite an effective approach even before the coining of the term in 2006.

For the technological interface, the goal is to develop an open-source web application that facilitates crowd-tagging of before and after aerial photographs. The iCoast web application[37] has been customized to make it easier to conduct oblique aerial imagery comparisons, as well as to reuse the crowd-tagging system for future storms and imagery comparison projects. Agile software development practices (Sletholt et al. 2011) facilitated the rapid development of multiple iCoast prototypes iteratively developed in Matlab, Ruby, and PHP. The "Think-Aloud Protocol" (Lewis 1982) was implemented during the usability tests with the USGS coastal scientists to elicit ways of designing an intuitive, self-instructive interface. iCoast also incorporates “responsive design” techniques to make it dynamically viewable on various resolution screens.

For the organizational interface, USGS coastal scientists embraced the idea of using crowdsourced data to improve prediction models and vulnerability assessments. To align with their conceptual schemas of coastal change processes, the iCoast tags were collaboratively developed with professional guidance from the USGS scientists through contextual interviews and observations. The naming and descriptions of the tags have evolved to ensure that they provide educational information about coastal hazards in a simple manner to the public while being scientifically accurate (see Figure 5). Integrating crowdsourcing practices into existing products and workflows is not new to the USGS, but it requires a deep consideration for how to design and articulate these crowdsourcing workflows to still meet the mission of the USGS.

For the policy interface, the iCoast project faced challenges with how to best adhere to Federal policies and regulations around engaging the public and managing crowd data, particularly in the networked world. The Privacy Act of 1974 specifies how personal information on citizens may be collected and stored. The Paperwork Reduction Act of 1980/1995 is intended to reduce the obligations of citizens to respond to government surveys. The Office of Management and Budget (OMB) sent a memorandum[38] in April 2010 to address the use of social media and web-based interactive technologies in relation to OMB’s Paperwork Reduction Act to establish

Figure 5. Screenshot of iCoast showing tags that correlate with the terminology used in the USGS coastal change predictive models (http://coastal.er.usgs.gov/icoast/).

"a system of transparency, public participation, and collaboration." However, these dated policies do not always reflect and influence what occurs in practice. These policies and legal documents are written in ways that conflict with established methods of conducting participatory design and agile software development to create public-facing prototypes for the purposes of improving user experience and engagement early on in the project.

6.7. The future plans for iCoast

The iCoast project is presented here to show how to apply the framework to strategically create different crowdsourcing configurations. Future work will involve analyzing iCoast to assess the quality of these crowdsourced data, similar to assessments of the quality of volunteered geographic information in OpenStreetMap (Haklay 2010; Jackson et al. 2013).

The analysis of the iCoast data will focus on differences in speed, quantity, and quality of the annotations within and between the different crowd types with varying levels of coastal expertise. Annotations from coastal scientists will be treated as the gold standard dataset. Similar analysis can be conducted on individual users and particular post-storm aerial photographs. If there are clear differences in quality across different crowds, then the annotation quality of certain crowd types can be weighted differently.

iCoast has the potential to enhance the science of coastal change and allow for more accurate predictions of coastal change to benefit emergency managers and coastal planners. The USGS is beginning to explore ways of coupling crowdsourced data with coastal change predictive models to quantify the expected visual evidence of coastal erosion, damage to human and natural coastal infrastructure, and post-storm recovery efforts. Ultimately, the goal of iCoast is to increase public awareness of coastal vulnerabilities to extreme storms, especially to those living along the coast.

7. Implications for applying the crowdsourcing framework

The vignettes illustrated the evolution from spontaneous crowdsourcing efforts to more formalized, well-tested crowdsourcing workflows to better inform the emergency management community. The best practices extracted from these vignettes guided the development of a framework that models the key dimensions of crowdsourcing in the crisis domain. The Crisis Crowdsourcing Framework offers guidelines for strategically designing and developing crowdsourcing systems configurable for each project and associated crisis event. The framework also facilitates an awareness of the articulation work that may be invisible to help determine the type of interfaces hindering or enabling the project.

The crowd work itself is not hard to do and typically designed to be quick and simple. The challenging part emerged from the invisible coordination work among the digital volunteers discovering and improvising ways to align the convergence of crowds, information, and resources during disasters. This articulation work of coordinating in the networked world was needed because the social, technological, organizational, and policy interfaces were misaligned. It is at these interfaces where the articulation work happened and where innovation was needed.

7.1. Modeling articulation work in a networked world

In 1999, Bowker and Star discerned that one of the key CSCW challenges in designing collaborative systems was modeling articulation work particularly for crisis situations that require situated actions and adaptation of plans Suchman (1987). Catastrophic events like the 2010 Haiti earthquake offered stakeholders an opportunity to improvise, adapt, and even make exceptions to official rules and procedures because people wanted to help, especially if it meant saving lives.

The Crisis Crowdsourcing Framework can be instructive not only to the crisis informatics community and the practitioners and digital volunteers within it, but also to the CSCW community more broadly. This framework is an attempt at modeling articulation work based on an emerging form of cooperative work formalized from improvised uses of networking technologies. The crisis domain is an area of research and practice that often attracts attention because it is problem-driven by nature and is an application domain where improvisation can lead to innovation with broad societal impacts. In some ways, the purpose of the Crisis Crowdsourcing Framework is to help different stakeholders in this field articulate ways of aligning the key dimensions and contingencies associated with crowdsourcing in the crisis domain. The STOP interfaces are the interaction mechanisms for enabling and managing the coordination work involved in crowdsourcing when weaving together the types of crowds, tasks, and interaction flows in the spatiotemporal context of disaster management.

STOP interfaces are the interaction mechanisms for enabling and managing the coordination work involved in crowdsourcing after identifying and integrating the other five dimensions previously discussed. The opportunities for innovation are occurring at the STOP interfaces. Coordination conflicts are resolved when these interfaces are interwoven and aligned. Although CSCW tends to focus on developing technological interfaces in terms of designing computer-based systems, this community also deeply considers the social and organizational interfaces and now the policy interface (Jackson et al. 2014). Understanding the cooperative work that happens during crisis situations requires a deeper consideration of the policy interface, where the policies may conflict with the ways in which coordination is occurring in the networked world during disasters. The STOP interfaces are intended to be considered collectively to understand the interdependencies and interconnections between these interfaces.

Social media and emerging ICTs, like free cloud computing services, have been improvised and adapted to enable cooperative work between different formal and informal crowds for disaster management purposes. Multiple configurations of crowdsourcing are produced from fluidly meshing the coordinated work across a myriad of ICTs or "mechanisms of interaction," similar to Schmidt's (1993) description of where "the articulation of cooperative work" takes place. Many configurations are possible, as is evident in the vignettes, but they all share common, salient dimensions resulting in best practices for reducing the complexity of coordinating at the STOP interfaces. Baker and Millerand (2007) highlight the importance of articulation work for "community-building" and "long-term information infrastructure building." Stakeholders in the crisis informatics field are trying to build a community that leverages the cyberinfrastructure. The challenge is to design sustainably to enable long-term crowdsourcing efforts for future crises, while keeping abreast of emerging ICTs.

Although there are a growing number of empirical studies in crisis informatics like Starbird and Palen (2013) that describe the articulation work of specific crisis crowdsourcing efforts, the purpose of this paper and the Crisis Crowdsourcing Framework is to offer a high-level interpretation of the lessons learned from the evolution of spontaneous digital volunteerism to more formalized crowdsourcing workflows currently deployed. The series of vignettes provide a window into the evolution of crisis crowdsourcing and recent best practices, but it is not an exhaustive list of all the public engagement and social media-related activities that have happened in the crisis domain. The vignettes illuminated the crisis crowdsourcing interfaces that have formalized into best practices for reducing the complexity of self-organizing and integrating crowdsourcing into traditional methods, formal structures, and official policies associated with emergency management. The spontaneous and emergent crowdsourcing efforts uncovered an urge to align the information needs of the emergency management community with the wisdom of the crowd, in all its variations and configurations. What has resulted in attempting to mainstream crisis crowdsourcing is the formalization of the articulation work for managing the planning, coordinating, and negotiating efforts needed to enable crisis crowdsourcing thus far.

7.2. Limitations of the crisis crowdsourcing framework

Although the Crisis Crowdsourcing Framework is intended to be a comprehensive approach to developing a crowdsourcing project in the crisis domain, opportunities for refining, expanding, and critiquing the framework are apparent. For example, the framework does not include an examination of crowd motivation and ethical issues with participating in digital volunteerism or ways of analyzing a crowdsourcing system. Crisis informatics researchers like Starbird

(2012) have started to create classifications delineating the primary motivations for participating in crowdwork (i.e., benevolence, social capital, symbolic capital, self-improvement, entertainment, and economic capital). Sharma (2010) also offers a "crowdsourcing critical success factor model" emphasizing the importance of aligning the motivations of the crowd to the crowdsourcing initiative. The type of crowd as well as their motivations and incentives for participating in these efforts will likely affect the speed and quality of the crowdsourcing project.

Another area of discussion not addressed in the framework is analyzing and evaluating the effectiveness of certain crowdsourcing configurations. Although most crisis crowdsourcing projects tend to be volunteer-based or unpaid, it is worth considering how monetary or other reward-based systems can affect the quality of the crowdsourcing project. In an email interview, Robert Munro pointed out that the Haitian diaspora tended to be more accurate and efficient, often ten times faster at geolocating information than non-Haitians, particularly the digital volunteers that curated these messages in the Ushahidi-Haiti crisis map. He questions whether digital volunteerism may undercut the cost of supporting paid crowd workers. For instance, "the median time for the Kreyòl-speakers to locate messages was under 5 min. For the students working independently of the Haitian population, it was over 4 hours" (Munro 2012, p. 23). The speed in which these sourcing practices were complete "contributed to the situational awareness of the responders, helping [to] track the changing conditions as populations moved internally," which ultimately informed the planning of relief aid operations (Munro 2012).

8. Conclusion

The Crisis Crowdsourcing Framework provides guidance on delineating the key dimensions to consider when developing a crowdsourcing project to inform emergency management. It encourages an articulation and awareness of the invisible coordination work enabling or hindering the project by strategically determining the why, who, what, when, where, and how aspects of a crowdsourcing system to better manage the articulation work involved with coordinating across these different dimensions. There can be multiple crowdsourcing configurations employed within a single project to maximize the benefits of one configuration and minimize the tradeoffs of another.

Innovation is happening at the social, technological, organizational, and policy interfaces enabling crowdsourcing to be formalized and integrated into official products and services. Perceptions around public engagement and user-generated content are evolving with the formalization of crowdsourcing, citizen science, and online collaboration projects in general. There is a move towards seeking collaborative, integrative, and strategic approaches, which is changing the values, praxis, and norms around how to engage with the general public as voluntary participants as well as stakeholders, especially for emergency management purposes. The Crisis Crowdsourcing Framework engenders an interdisciplinary and multi-stakeholder approach to developing robust and sustainable crowdsourcing systems by reducing the complexity of managing and coordinating crowd work. There is a need to move beyond informing just the design of technological interfaces to also the design of social, organizational, and policy interfaces that affect coordination and interaction in the networked world, especially during times of crisis

9. Notes

1. https://www.mturk.com/
2. http://crisismappers.net/
3. http://hot.openstreetmap.org/
4. http://crisiscommons.org/
5. http://vimeo.com/9182869
6. http://www.disruptivegeo.com/tag/nextview/
7. https://hiu.state.gov/ittc/ittc.aspx
8. http://tasks.hotosm.org
9. http://mapgive.state.gov/
10. http://haiti.ushahidi.com/
11. http://crowdmap.com
12. http://blog.standbytaskforce.com/about/
13. http://irevolution.net/2011/03/08/volunteers-behind-libya-crisis-map/
14. http://blog.standbytaskforce.com/about/activation-criteria/
15. http://digitalhumanitarians.com/
16. http://irevolution.net/2012/12/06/digital-disaster-response-typhoon/
17. http://corp.geofeedia.com/
18. http://earthquake.usgs.gov/earthquakes/dyfi/
19. http://earthquake.usgs.gov/earthquakes/ted/
20. http://www.ted.com/talks/erik_hersman_on_reporting_crisis_via_texting.html
21. https://docs.google.com/document/d/1QmSm4P9Bj-FWqqwoMzOpwnZ7dYzMfrQ-Qz5ipEiBIlY/edit?hl=en_US
22. http://standbytaskforce.ning.com/
23. http://www.wilsoncenter.org/event/getting-little-help-our-friends-crowdsourcing-and-usaid-development-credit-loans
24. http://www.giscorps.org/
25. http://irevolution.net/2010/12/29/crowdsourcing-crowdfeeding-snowmageddon/

26. http://blog.ushahidi.com/index.php/2010/08/02/russia-crowdsourcing-assistance-for-victims-of-wildfires & http://irevolution.net/2011/04/03/icts-limited-statehood/
27. https://twitter.com/tos
39. The disaster lifecycle diagram was taken from a Study Guide and Course Text for a course on "Aim & Scope of Disaster Management" at the University of Wisconsin-Madison Disaster Management Center, prepared by Don Schramm and Richard Hansen in 1986/1991. http://epdfiles.engr.wisc.edu/dmcweb/AA02AimandScopeofDisasterManagement.pdf
28. http://hot.openstreetmap.org/projects/haiti-2
29. http://www.un-spider.org/crowdsource-mapping
30. http://coastal.er.usgs.gov/hurricanes/erosionhazards/
31. http://olga.er.usgs.gov/hurricane_erosion_hazards/
32. http://earthquake.usgs.gov/earthquakes/dyfi/
33. http://landslides.usgs.gov/dysi/
34. https://www.avo.alaska.edu/ashfall/ashreport.php
35. http://www.tomnod.com/
36. http://publiclab.org/wiki/mapmill
37. http://coastal.er.usgs.gov/icoast/
38. http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/SocialMediaGuidance_04072010.pdf

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